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(54) **Sample separating apparatus and method, and substrate manufacture method**

Vorrichtung und Verfahren zum Spalten

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Description

[0001] The present invention relates to a sample separating apparatus and method, and a substrate manufacturing method and, for example, to an apparatus and method of separating a plate-like sample having an internal fragile layer at the fragile layer, a sample support apparatus used in the separating apparatus, and a substrate manufacturing method using the separating apparatus.

DESCRIPTION OF THE RELATED ART

[0002] A substrate (SOI substrate) having an SOI (Silicon On Insulator) structure is known as a substrate having a single-crystal Si layer on an insulating layer. A device using this SOI substrate has many advantages that cannot be achieved by ordinary Si substrates. Examples of the advantages are as follows.

(1) The integration degree can be increased because dielectric isolation is easy.
(2) The radiation resistance can be increased.
(3) The operating speed of the device can be increased because the stray capacitance is small.
(4) No well step is necessary.
(5) Latch-up can be prevented.
(6) A completely depleted field-effect transistor can be formed by thin film formation.

[0003] Since an SOI structure has the above various advantages, researches have been made on its formation method for several decades.

[0004] As one SOI technology, an SOS (Silicon On Sapphire) technology by which Si is heteroepitaxially grown on a single-crystal sapphire substrate by CVD (Chemical Vapor Deposition) has been known for a long time. This SOS technology was once recognized as the most matured SOI technology. However, the SOS technology has not been put into practical use to date because, e.g., a large amount of crystal defects are produced by lattice mismatch in the interface between the Si layer and the underlying sapphire substrate, aluminum that forms the sapphire substrate mixes in the Si layer, the substrate is expensive, and it is difficult to obtain a large area.

[0005] Various SOI technology appeared following the SOS technology. For these SOI technologies, various methods have been examined aiming at reducing crystal defects or manufacturing cost. There are a method of implanting oxygen ions into a substrate to form a buried oxide layer, a method of bonding two wafers via an oxide film and polishing or etching one of the wafers to leave a thin single-crystal Si layer on the oxide film, and a method of implanting hydrogen ions to a predetermined depth from the surface of an Si substrate having an oxide film, bonding the Si substrate to the other substrate, and peeling the latter substrate (the other substrate) by a heat treatment while leaving a thin single-crystal Si layer on the oxide film.

[0006] The present applicant has disclosed a new SOI technology in Japanese Patent Laid-Open No. 5-21338. In this technology, a first substrate obtained by forming a non-porous single-crystal layer (including a single-crystal Si layer) on a single-crystal semiconductor substrate having a porous layer is bonded to a second substrate via an insulating layer (SiO_2), and the two substrates are separated from the porous layer to transfer the non-porous single-crystal layer to the second substrate. This technology is advantageous in that the SOI layer has high film thickness uniformity, the crystal defect density in the SOI layer can be decreased, the SOI layer has high surface planarity, no expensive special fabrication apparatus is necessary, and SOI substrates having SOI films about a few hundred ~ to 10 μm thick can be fabricated by the same fabrication apparatus.

[0007] In addition, the present applicant has disclosed another technology in Japanese Patent Laid-Open No-7-302889 in which, after the first and second substrates described above are bonded, the first substrate is separated from the second substrate without breaking, and the separated first substrate is reused by smoothening the surface and again forming a porous layer. Since the first substrate can be economically used, this technology has the advantages that the fabrication cost can be largely reduced and the fabrication process is also simple.

[0008] In the above technologies, however, when the two bonded substrates are separated it is necessary to prevent damages to the substrates and protect the fabrication apparatus and the like from contamination caused by the generation of particles.

SUMMARY OF THE INVENTION

[0009] In a first aspect, the present invention provides a method of separating a plate-like sample at an internal fragile layer as defined in claim 1, the method comprising the steps of:

holding the sample between respective contact portions of two opposing holding portions so as to sandwich the sample; and
ejecting a fluid towards the fragile layer at the edge of the sample so as to inject fluid into the sample, thereby separating the sample,

characterized in that:
the contact portions are configured so as to cause a face of the held sample to become corrugated during the step of ejecting the fluid.

[0010] In a second aspect, the present invention provides a method of manufacturing a substrate, the method comprising the steps of:

sequentially forming a porous layer and a non-po-

rous layer on a first substrate to produce a first composite slab;
forming an insulating layer on a second substrate (14) to produce a second composite slab;
bringing the non-porous layer and the insulating layer into contact and bonding the first and second composite slabs to form a plate-like sample in which the porous layer is an internal fragile layer; and
separating the plate-like sample at the porous layer by a method as described above.

[0011] In a third aspect, the present invention provides a support apparatus accordind to claim 7.

[0012] In a fourth aspect, the present invention provides a support apparatus as defined in claim 8.

[0013] In a fifth aspect, the present invention provides a support apparatus as defined in claim 9.

[0014] In a sixth aspect, the present invention provides a separating device for separating a plate-like sample at an internal fragile layer, the separating apparatus comprising:

a jet unit for ejecting a fluid towards the fragile layer in the direction of the thickness the sample; and
a support apparatus for supporting the sample in the path of the fluid, the support apparatus having the features recited above in one of the third, fourth or fifth aspects.

[0015] Further objects, features and advantages of the present invention will become apparent from the following detailed description of embodiments of the present invention with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016]

Figs. 1A to 1E are views for explaining a method of manufacturing an SOI substrate;
Fig. 2 is a view showing the schematic arrangement of a separating apparatus according to the first embodiment of the present invention;
Fig. 3 is a perspective view of substrate holding portions according to the first example of the first embodiment;
Fig. 4 is a front view of the substrate holding portion according to the first example of the first embodiment;
Fig. 5 is a sectional view of the substrate holding portions according to the first example of the first embodiment;
Fig. 6 is a view showing a modification of the substrate holding portion according to the first example of the first embodiment;
Fig. 7 is a view showing another modification of the substrate holding portion according to the first example of the first embodiment;
Fig. 8 is a view showing still another modification of the substrate holding portion according to the first example of the first embodiment;
Fig. 9 is a view showing still another modification of the substrate holding portion according to the first example of the first embodiment;
Fig. 10 is a front view of a substrate holding portion according to the second example of the first embodiment;
Fig. 11 is a sectional view of the substrate holding portions according to the second example of the first embodiment;
Fig. 12 is a perspective view of substrate holding portions according to the third example of the first embodiment;
Fig. 13 is a perspective view showing a modification of the substrate holding portions according to the third example of the first embodiment;
Fig. 14 is a perspective view of substrate holding portions according to the fourth example of the first embodiment;
Fig. 15 is a perspective view showing a modification of the substrate holding portions according to the fourth example of the first embodiment;
Fig. 16 is a perspective view of substrate holding portions according to the fifth example of the first embodiment;
Fig. 17 is a front view of the substrate holding portion according to the fifth example of the first embodiment;
Fig. 18 is a perspective view of substrate holding portions according to the sixth example of the first embodiment;
Fig. 19 is a front view of the substrate holding portion according to the sixth example of the first embodiment;
Fig. 20 is a perspective view showing a modification of the substrate holding portions according to the sixth example of the first embodiment;
Fig. 21 is a perspective view showing another modification of the substrate holding portions according to the sixth example of the first embodiment;
Fig. 22 is a perspective view showing still another modification of the substrate holding portions according to the sixth example of the first embodiment;
Fig. 23 is a perspective view showing still another modification of the substrate holding portions according to the sixth example of the first embodiment;
Fig. 24 is a perspective view showing still another modification of the substrate holding portions according to the sixth example of the first embodiment;
Fig. 25A and 25B are views showing a force acting on a bonded substrate stack in the presence and absence of a V-shaped groove;

Fig. 26 is a view showing the schematic arrangement of a separating apparatus in a comparative example not falling within the scope of the invention claimed;

Fig. 27 is a perspective view of part of the separating apparatus shown in Fig. 26;

Fig. 28 is a view schematically showing separation processing;

Fig. 29 is a view showing the schematic arrangement of a separating apparatus of a modification of the comparative example, also not falling under the scope of the claims.

Fig. 30 is a view showing the schematic arrangement of substrate holding portions of a separating apparatus according to the second embodiment of the invention;

Fig. 31 is a view showing the schematic arrangement of a substrate holding portion (on the first substrate side) in a modification of the second embodiment; and

Fig. 32 is a view showing the schematic arrangement of the other substrate holding portion (on the second substrate side) in the modification of the second embodiment.

Figs. 33A to 33E are views for explaining another method of manufacturing an SOI substrate.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0017] Figs. 1A to 1E are views for explaining a method of manufacturing an SOI substrate.

[0018] Referring to Fig. 1A, a single-crystal Si substrate 11 is prepared, and a porous Si layer 12 is formed on the surface of the single-crystal Si substrate 11 by anodizing. Referring to Fig. 1B, a non-porous single-crystal Si layer 13 is epitaxially grown on the porous Si layer 12. With this process, a first substrate 10 is formed.

[0019] Referring to Fig. 1C, a second substrate 20 having an insulating layer (e.g., an SiO_2 layer) 15 formed on the surface of a single-crystal Si substrate 14 is prepared. The first substrate 10 and the second substrate 20 are brought into contact with each other at room temperature such that the non-porous single-crystal Si layer 13 opposes the insulating layer 15. After this, the first substrate 10 and the second substrate 20 are bonded by anode bonding, pressing, heating, or a combination thereof. With this process, the non-porous single-crystal Si layer 13 and the insulating layer 15 are firmly bonded. The insulating layer 15 may be formed on the single-crystal Si substrate 14 side, as described above, on the non-porous single-crystal Si layer 13 as will be described later, or on both the single-crystal Si substrate 14 and the non-porous single-crustal Si layer 13 sides as far as the state shown in Fig. 1C is obtained by bringing the first and second substrates into contact.

[0020] Referring to Fig. 1D, the two substrates bonded to each other are separated at the porous Si layer 12. The second substrate side (10" + 20) has a multilayered structure of a porous Si layer 12", single-crystal Si layer 13, insulating layer 15, and single-crystal Si substrate 14. On the first substrate side (10'), a porous Si layer 12' is formed on the single-crystal Si substrate 11.

[0021] After separation, the remaining porous Si layer 12' is removed from the substrate 10'. The surface of the substrate 10' is planarized, as needed, so the substrate 10' is used again as a single-crystal Si substrate 11 for forming a first substrate 10.

[0022] After the bonded substrate stack is separated, in Fig. 1E, the porous layer 12" on the second substrate side (10" + 20) is selectively removed. With this process, a substrate having a multilayered structure of the single-crystal Si layer 13, insulating layer 15, and single-crystal Si substrate 14, i.e., an SOI structure is obtained.

[0023] Figs. 33A to 33E are views for explaining another method of manufacturing an SOI substrate.

[0024] Referring to Fig. 33A, a single-crystal Si substrate 11 is prepared, and a porous Si layer 12 is formed on the surface of the single-crystal Si substrate 11 by anodizing. Referring to Fig. 33B, a single-crystal Si layer 13 as a non-porous layer is epitaxially grown on the porous Si layer 12. After this, the surface of the single-crystal Si layer 13 is oxidized to form an SiO_2 layer 15. With this process, a first substrate 10 is formed.

[0025] Referring to Fig. 33C, a single-crystal Si substrate 14 is prepared as a second substrate 20. The first substrate 10 and the second substrate 20 are brought into contact with each other at room temperature such that the SiO_2 layer 15 of the first substrate 10 opposes the second substrate 20. The first substrate 10 and the second substrate 20 are bonded by anode bonding, pressing, heating, or a combination thereof. With this process, the second substrate 20 and the SiO_2 layer 15 are firmly bonded. The SiO_2 layer 15 may be formed on the single-crystal Si substrate 11 side, on the second substrate 20, as described above, or on both the single-crystal Si substrate 11 and the second substrate 20 sides as far as the state shown in Fig. 33C is obtained by bringing the first and second substrates into contact.

[0026] Referring to Fig. 33D, the two substrates bonded to each other are separated at the porous Si layer 12. The second substrate side has a multilayered structure of a porous Si layer 12", single-crystal Si layer 13, SiO_2 layer 15, and single-crystal Si substrate 14. On the first substrate 10' side, the porous Si layer 12' is formed on the single-crystal Si. substrate 11.

[0027] After separation, the remaining porous Si layer 12' is removed from the substrate 10'. The surface of the substrate 10' is planarized, as needed, so the substrate 10' is used again as a single-crystal Si substrate 11 for forming a first substrate 10.

[0028] After the bonded substrate stack is separated, in Fig. 33E, the porous layer 12" on the second substrate side (10" + 20) is selectively removed. With this process, a substrate having a multilayered structure of the single-crystal Si layer 13, insulating layer 15, and

single-crystal Si substrate 14, i.e., an SOI structure is obtained.

[0029] As the second substrate, in addition to a single-crystal Si substrate, an insulating substrate (e.g., a substrate of silica glass) or a transparent substrate (e.g., a substrate of silica glass) can be used.

[0030] In this example, to facilitate processing of bonding two substrates and separating them, a porous Si layer 12 having a fragile structure is formed in the separation region. In place of the porous layer, a microcavity layer may be formed. A microcavity layer can be formed by, e.g., implanting ions into a semiconductor substrate.

[0031] The substrate manufactured by the above manufacturing method can be applied not only to manufacture a semiconductor device but also to manufacture a microstructure.

[0032] In this example, in the step shown in Fig. 1D or 33D, i.e., in the step of separating the two substrates bonded to each other (to be referred to as a bonded substrate stack hereinafter), a separating apparatus for selectively ejecting a high-pressure liquid or gas (fluid) to the porous Si layer as a separation region is used to separate the substrate stack into two substrates at the separation region.

[0033] Preferred embodiments of the present invention will be described below with reference to the accompanying drawings.

[First Embodiment]

[Basic Arrangement of Separating Apparatus]

[0034] This separating apparatus uses the water jet method. Generally, the water jet method ejects a high-speed, high-pressure stream of water (when a hard object is to be cut, an abrasive is added to water) upon an object to, e.g., cut or process a ceramic, a metal, a concrete, a resin, a rubber, or a wood member, remove a coating film from the surface, or clean the surface ("Water Jet", Vol. 1, No. 1, page 4, (1984)). Conventionally, the water jet method is used to perform the above-described cutting, processing, remove a coating film, or clean the surface mainly by partially removing the material.

[0035] This separating apparatus ejects a high-speed, high-pressure stream of fluid to the porous layer (separation region) of the bonded substrate stack as a fragile structure portion in the direction of substrate surface to selectively break the porous layer, thereby separating the substrate at the porous layer. The stream will be referred to as a "jet" hereinafter. The fluid forming a jet will be referred to as a "jet medium". As the jet medium, it is possible to use an organic solvent such as water or alcohol, an acid such as fluoric acid or nitric acid, an alkali such as potassium hydroxide, a gas such as air, nitrogen gas, carbonic acid gas, rare gas, or an etching gas, or a plasma.

[0036] When this separating apparatus is to be applied to manufacture a semiconductor device, e.g., separate a bonded substrate stack, pure water with minimum impurity metals or particles is preferably used as the jet medium. However, since separation processing is a perfect low-temperature process, water with high purity need not always be used as the jet medium, and the substrate may be cleaned after completion of separation processing.

[0037] In this separating apparatus, a jet is ejected to the porous layer (separation region) exposed to the side surface of the bonded substrate stack, thereby removing the porous layer from the peripheral portion to the central portion. With this process, the bonded substrate stack is separated into two substrates by removing only the separation region with low mechanical strength without damaging the main body. Even when the side surface of the bonded substrate stack is covered with some thin layer, and the porous layer is not exposed, the thin layer can be removed by the jet, so the bonded substrate stack can be separated by the above-described method.

[0038] To separate the bonded substrate stack only by the cutting force of jet, a high pressure of several thousand kgf/cm^2 or more must be applied to the jet medium. In this case, the outer peripheral portion of the bonded substrate stack may be damaged, or the internal pressure of the separation region may increase to break the bonded substrate stack.

[0039] To avoid this situation, the pressure to be applied to the jet medium is preferably set to be as low as about 500 kgf/cm^2. When such a low-pressure jet is employed, the bonded substrate stack is separated by injecting the jet medium into the bonded substrate stack to expand and split it into two substrates rather than by colliding the jet against the porous layer to cut the porous layer by impact. Therefore, offcut is rarely produced, and damages to substrates decrease. In addition, the jet medium need contain no abrasive.

[0040] At the peripheral portion of the bonded substrate stack, the effect for splitting the bonded substrate stack into two substrates effectively acts when a V-shaped (concave) groove is formed in the bonded substrate stack along the side surface. Figs. 27A and 27B are views showing a force acting on the bonded substrate stack in the presence and absence of a V-shaped groove. Fig. 27A shows a bonded substrate stack having a V-shaped groove 22. Fig. 27B shows a bonded substrate stack having no V-shaped groove.

[0041] As shown in Fig. 27A, in the bonded substrate stack having the V-shaped groove 22, a force (to be referred to as a separation force hereinafter) is applied outward from the center of the bonded substrate stack, as indicated by an arrow 23. On the other hand, as shown in Fig. 27B, in the bonded substrate stack with a convex side surface, a force is applied inward from the side surface of the bonded substrate stack, as indicated by an arrow 24. In the bonded substrate stack having a convex side surface, the separation force does not act

unless the side surface of the porous layer 12 as the separation region is removed by a jet 21.

[0042] Even when a thin film is formed on the side surface of the bonded substrate stack, the separation force acts on the bonded substrate stack as far as the bonded substrate stack has the V-shaped groove 22, as shown in Fig. 27A, so the thin layer can be easily broken.

[0043] To prevent damages to the substrates, the separation force in the axial direction of the bonded substrate stack is preferably set to be several hundred gf/ cm^2.

[0044] To effectively use the jet, a width W1 of the V-shaped groove 22 is preferably equal to or larger than a diameter d of the jet 21. For example, assume that each of the first substrate (10) and the second substrate (20) has a thickness of about 1 mm, and the bonded substrate stack has a thickness of about 2 mm. Since the width W1 of the V-shaped groove 22 is normally around 1 mm, the diameter of the jet is preferably 1 mm or less. Since a general water jet apparatus uses a jet with a diameter of approximately 0.1 to 0.5 mm, such a general water jet apparatus (e.g., a water jet nozzle) can be used.

[0045] The nozzle for ejecting a jet can have not only a circular shape but any other shapes. For example, when a slit-like nozzle is employed to eject a jet having a long rectangular section, the jet can be efficiently injected into the separation region (inserted between the two substrates).

[0046] The jet ejection conditions are determined in accordance with the type of separation region (e.g., a porous layer) or the shape of the side surface of the bonded substrate stack. Important parameters as the jet ejection conditions are the pressure applied to the jet medium, the jet scanning speed, the width or diameter of the nozzle (the nozzle diameter is almost the same as the jet diameter), the nozzle shape, the distance between the nozzle and the separation region, and the flow rate of the jet medium.

[0047] The following techniques are used to separate the bonded substrate stack. 1) The jet is injected into the bonding interface parallel to the bonding interface while the nozzle is scanned along the bonding interface. 2) The jet is injected into the bonding interface parallel to the bonding interface while the bonded substrate stack is scanned. 3) The jet is injected into the bonding interface parallel to the bonding interface and simultaneously scanned in a fan shape at a pivot near the nozzle. 4) The jet is injected into the bonding interface parallel to the bonding interface while the bonded substrate stack is rotated about nearly the center of the bonded substrate stack (this technique is particularly effective when the bonded substrate stack has a disk shape). The jet need not always be ejected to be perfectly parallel to the bonding interface.

[0048] Fig. 2 is a view showing the schematic arrangement of a separating apparatus according to the first embodiment of the present invention. To separate a bonded substrate stack by a low-pressure jet, a separating apparatus 100 supports the bonded substrate stack such that the separation force efficiently acts on the bonded substrate stack. As a specific example, the separating apparatus 100 supports a bonded substrate stack such that the bonded substrate stack can expand at its central portion by the pressure of the jet medium injected into the bonded substrate stack. As another example, the separating apparatus 100 supports a bonded substrate stack such that the bonded substrate stack can corrugate by the pressure of the jet medium injected into the bonded substrate stack.

[0049] The separating apparatus 100 has substrate holding portions 120 and 150 having vacuum chuck mechanisms. A bonded substrate stack 101 is sandwiched by the substrate holding portions 120 and 150 and held. The bonded substrate stack 101 has a porous layer 101b as an internal fragile structure and is separated into two substrates 101a and 101c at the porous layer 101b by the separating apparatus 100. In this separating apparatus 100, the bonded substrate stack is set such that the substrate 101a is placed on the first substrate (10') side in Fig. 1D or 41D and the substrate 101c is placed on the second substrate (10" + 20) side in Fig. 1D or 41D.

[0050] The substrate holding portions 120 and 150 are present on the same rotary axis. The substrate holding portion 120 is coupled to one end of a rotary shaft 104 which is rotatably axially supported by a support base 109 through a bearing 108. The other end of the rotary shaft 104 is coupled to the rotary shaft of a motor 110. The rotational force generated by the motor 110 rotates the bonded substrate stack 101 vacuum-chucked by the substrate holding portion 120. In separating the bonded substrate stack 101, the motor 110 rotates the rotary shaft 104 at a designated rotation speed in accordance with an instruction from a controller (not shown).

[0051] The substrate holding portion 150 is coupled to one end of a rotary shaft 103 which is rotatably and slidably axially supported by the support base 109 through a bearing 111. The other end of the rotary shaft 103 is coupled to an air cylinder 112 fixed on the support base 109. When the air cylinder 112 pushes the rotary shaft 103, the bonded substrate stack 101 is pressed by the substrate holding portion 150.

[0052] The substrate holding portions 120 and 150 can be detached from the rotary shafts 104 and 103, respectively. The substrate holding portions 120 and 150 have one or a plurality of suction holes 181 and 182 as vacuum chuck mechanism, respectively. The suction holes 181 and 182 communicate with rotary seal portions 104a and 103a through the rotary shafts 104 and 103, respectively. The rotary seal portions 104a and 103a are coupled to vacuum lines 104b and 103b, respectively. These vacuum lines 104b and 103b have solenoid valves. By controlling the solenoid valves, setting/ removal of the bonded substrate stack 101 can be con-

trolled.

[0053] The substrate holding portions 120 and 150 hold the bonded substrate stack 101 such that the separation force efficiently acts on the bonded substrate stack 101 in separation processing. Specific arrangements of the substrate holding portions 120 and 150 will be described later.

[0054] Substrate separation processing using this separating apparatus 100 will be described below.

[0055] To set the bonded substrate stack 101 in the separating apparatus 100, first, the rotary shaft 103 is retracted by the air cylinder 112 to set a predetermined interval between the chucking surfaces of the substrate holding portions 120 and 150. After the bonded substrate stack 101 is mounted on an alignment shaft 113, the air cylinder 112 pushes the rotary shaft 103, so the bonded substrate stack 101 is pressed and held (the state shown in Fig. 2). The alignment shaft 113 is rotatably axially supported by the support base 109 through bearings 105 and 107.

[0056] In this embodiment, the bonded substrate stack 101 is held not by vacuum chucking but by the pressing force of the air cylinder 112. The pressing force is preferably about 100 to 2000gf. The bonded substrate stack 101 may be vacuum-chucked, as a matter of course. In separation processing, the air cylinder 112 is preferably controlled to maintain a predetermined interval between the substrate holding portions 120 and 150.

[0057] A jet medium (e.g., water) is sent from a pump 114 to a nozzle 102, and processing waits until the jet ejected from the nozzle 102 stabilizes. When the jet stabilizes, a shutter 106 is opened to inject the jet into the separation region of the bonded substrate stack 101. At this time, the bonded substrate stack 101 is rotated by the motor 110. The rotary shaft 104, substrate holding portion 120, bonded substrate stack 101, substrate holding portion 150, and rotary shaft 103 integrally rotate.

[0058] When the jet is injected, a separation force due to the pressure of the jet medium continuously injected into the porous layer 101b as a fragile structure acts on the bonded substrate stack 101 to break the porous layer 101b which connects the substrates 101a and 101c. With this processing, the bonded substrate stack 101 is separated into two substrates in about 2 min.

[0059] When the bonded substrate stack 101 is separated into two substrates, the shutter 106 is closed, and the operation of pump 114 is stopped. By stopping rotation of the motor 110 and controlling the above-described electromagnetic valves, the separated substrates are vacuum-chucked by the substrate holding portions 120 and 150.

[0060] When the air cylinder 112 retracts the rotary shaft 103, the surface tension of the jet medium (e.g., water) is cut off to split the two physically separated substrates to both sides.

[0061] When the separation force is to efficiently act on the bonded substrate stack 101, the structure of the substrate holding portions 120 and 150 must be optimized. In this embodiment, the separation force is efficiently used by ensuring a space in which the bonded substrate stack deflects in separation processing. Preferable arrangements of substrate holding portions will be listed below. In the following examples, the substrate holding portions 120 and 150 have a symmetrical structure. However, the substrate holding portions 120 and 150 may have independent structures.

[First Example of Substrate Holding Portion]

[0062] Figs. 3 to 5 are views showing the arrangement of substrate holding portions according to the first example of the present invention. Fig. 3 is a perspective view, Fig. 4 is a front view, and Fig. 5 is a sectional view. Substrate holding portions 121 and 151 shown in Figs. 3 to 5 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0063] The substrate holding portions 121 and 151 of the first example have annular contact portions 121a and 151a which come into contact with the bonded substrate stack 101. With this structure, the bonded substrate stack 101 can deflect having "nodes" at a portion sandwiched by the contact portions 121a and 151a and "antinodes" near the central and peripheral portions of the bonded substrate stack 101. In other words, the substrate holding portions 121 and 151 have a structure in which the central portion of the bonded substrate stack 101 can expand in separation processing or a structure in which the bonded substrate stack 101 can corrugate in separation processing. When the substrate holding portions 121 and 151 having this structure are employed, the separation force can efficiently act inside the bonded substrate stack 101.

[0064] With the use of the substrate holding portions 121 and 151, separation progresses from the side surface portion of the bonded substrate stack 101 to the vicinity of the contact portions 121a and 151a in about 30 sec after the start of jet injection into the bonded substrate stack 101 (separation processing). In about 2 min after the start of separation processing, the bonded substrate stack 101 warps outward at its central portion to form "antinodes" and is completely separated.

[0065] The outer diameter of each of the contact portions 121a and 151a is preferably, e.g., 30 to 50 mm. The inner diameter of each of the contact portions 121a and 151a can be smaller than the outer diameter by, e.g., approximately 10 mm. However, for easy deflection of the substrate stack to be separated, the inner diameter of each of the contact portions 121a and 151a is preferably close to the outer diameter.

[0066] Any other substrate holding portion can provide the same effect as described above as far as it allows the bonded substrate stack 101 to deflect forming "nodes" and "antinodes". Figs. 6 to 9 are front views showing modifications of the substrate holding portion according to the first example. Reference numerals

122a, 152a, 123a, 153a, 124a, 154a, 125a, and 155a denote contact portions at which the substrate holding portions are in contact with the bonded substrate stack 101. Figs. 6 to 8 show examples of a contact portion having a polygonal shape with a hollow center. Fig. 9 shows an example of contact portion whose center is shifted from the center of the bonded substrate stack 101. These are examples of a stripe-shaped contact portion.

[Second Example of Substrate Holding Portion]

[0067] Fig. 10 and 11 are views showing the arrangement of substrate holding portions according to the second example of the present invention. Fig. 10 is a front view, and Fig. 11 is a sectional view. Substrate holding portions 126 and 156 shown in Figs. 10 and 11 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0068] The substrate holding portion 126 of this example has two annular contact portions 126a and 126b which come into contact with the bonded substrate stack 101. The substrate holding portion 156 has two annular contact portions 156a and 156b which come into contact with the bonded substrate stack 101. The substrate holding portions 126 and 156 of this example are particularly suitable to process a substrate stack with a large size (e.g., 8 inches or more).

[0069] With these substrate holding portions 126 and 156, the bonded substrate stack 101 can deflect having "nodes" at a circumferential portion sandwiched by the contact portions 126a and 156a and a portion sandwiched by the contact portions 126b and 156b, and "antinodes" near the intermediate portion between the contact portions and the peripheral portion of the bonded substrate stack 101.

[0070] When the substrate holding portions 126 and 156 having a structure in which the bonded substrate stack 101 deflects while corrugating or expanding near the central portion are employed, the separation force can efficiently act inside the bonded substrate stack 101.

[0071] With the use of the substrate holding portions 126 and 156, separation progresses from the side surface of the bonded substrate stack 101 to the vicinity of the outer contact portions 126a and 156a in about 30 sec after the start of jet injection into the bonded substrate stack 101 (separation processing). In about 30 sec after this, the bonded substrate stack 101 is separated to the outer contact portions 126b and 156b. In about 3 min after the start of separation processing, the bonded substrate stack 101 warps to form "nodes" and "antinodes" and is completely separated.

[0072] The widths of the contact portions (diameter difference) can be arbitrarily determined. However, for easy deflection of the substrate stack to be separated, the width of each contact portion is preferably small.

[0073] In this example, two sets of contact portions are formed. However, three or more sets of contact portions may be arranged.

[Third Example of Substrate Holding Portion]

[0074] Fig. 12 is a perspective view showing the arrangement of substrate holding portions according to the third example of the present invention. Substrate holding portions 127 and 157 shown in Fig. 12 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0075] The substrate holding portions 127 and 157 of this example have a plurality of contact portions 127a and 157a which come into contact with the bonded substrate stack 101, respectively. Stated differently, this structure has annular contact portions 121a and 151a of the first example with grooves 127b and 157b which divide the contact portions 121a and 151a, respectively.

[0076] The grooves 127b and 157b prevent the separation force from excessively acting in the vicinity of the central portion of the bonded substrate stack 101. More specifically, when the grooves 127b and 157b are formed, the jet medium injected into the central portion of the bonded substrate stack 101 can be appropriately discharged, so the jet medium pressure can be prevented from excessively increasing near the vicinity of the central portion. Therefore, the bonded substrate stack 101 can be prevented from breaking because of a portion of the porous layer, where the mechanical strength is locally high and separation progresses slowly.

[0077] With the use of the substrate holding portions 127 and 157, separation progresses from the side surface of the bonded substrate stack 101 to the vicinity of the contact portions 127a and 157a in about 30 sec after the start of jet injection into the bonded substrate stack 101 (separation processing). In about 2 min after the start of separation processing, the bonded substrate stack 101 warps outward at its central portion to form "antinodes" and is completely separated.

[0078] Fig. 13 is a perspective view showing a modification of the substrate holding portions shown in Fig. 12. Substrate holding portions 128 and 158 shown in Fig. 13 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0079] The substrate holding portion 128 of this modification has a plurality of columnar contact portions 128a forming a circle on a main body 128b. The substrate holding portion 158 has the same arrangement as that of the substrate holding portion 128. With the substrate holding portions 128 and 158 as well, the jet medium pressure can be prevented from excessively increasing inside the bonded substrate stack 101, so the bonded substrate stack 101 can be prevented from breaking.

[Fourth Example of Substrate Holding Portion]

[0080] Fig. 14 is a perspective view showing the ar-

rangement of substrate holding portions according to the fourth example of the present invention. Substrate holding portions 129 and 159 shown in Fig. 14 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0081] The substrate holding portion 129 of this example has two types of arcuated contact portions 129a and 129c which come into contact with the bonded substrate stack 101. To put it differently, the structure has the annular contact portions 126a and 126b of the second example with grooves 128b and 128d which divide the contact portions 126a and 126b, respectively. The substrate holding portion 159 has the same arrangement as that of the substrate holding portion 129.

[0082] With the use of the substrate holding portions 129 and 159, separation progresses from the side surface of the bonded substrate stack 101 to the vicinity of the outer contact portion 129a in about 30 sec after the start of jet injection into the bonded substrate stack 101 (separation processing). In about 30 sec after this, the bonded substrate stack 101 is separated to the vicinity of the inner contact portion 129c. In about 3 min after the start of separation processing, the bonded substrate stack 101 is completely separated while corrugating to form "nodes" and "antinodes".

[0083] By forming grooves 129b and 129d in the arcuated contact portions 129a and 129c, respectively (this also applies to the substrate holding portion 159), the jet medium pressure can be prevented from excessively increasing inside the bonded substrate stack 101. Hence, the bonded substrate stack 101 can be prevented from breaking because of a portion of the porous layer, where the mechanical strength is locally high and separation progresses slowly.

[0084] Fig. 15 is a perspective view showing a modification of the substrate holding portions shown in Fig. 14. Substrate holding portions 130 and 160 shown in Fig. 15 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0085] The substrate holding portion 130 of this modification has a plurality of columnar contact portions 130a forming double circles on a main body 130b. The substrate holding portion 160 has the same arrangement as that of the substrate holding portion 130. With the substrate holding portions 130 and 160 as well, the jet medium pressure can be prevented from excessively increasing inside the bonded substrate stack 101, so the bonded substrate stack 101 can be prevented from breaking.

[Fifth Example of Substrate Holding Portion]

[0086] Figs. 16 and 17 are views showing the arrangement of substrate holding portions according to the fifth example of the present invention. Fig. 16 is a perspective view, and Fig. 17 is a front view. Substrate holding portions 131 and 161 shown in Figs. 16 and 17 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0087] The substrate holding portions 131 and 161 of this modification has a plurality of columnar contact portions 131a and 161a on main bodies 131b and 161b, respectively. With the substrate holding portions 131 and 161, the bonded substrate stack 101 can deflect and corrugate having "nodes" at a portion sandwiched by the contact portions 131a and 161a, so the separation force can efficiently act inside the bonded substrate stack 101. In addition, since the jet medium discharge path is ensured, the jet medium pressure can be prevented from excessively increasing inside the bonded substrate stack 101. As a consequence, the bonded substrate stack 101 can be prevented from breaking because of a portion of the porous layer, where the mechanical strength is locally high and separation progresses slowly.

[0088] With the use of the substrate holding portions 131 and 161, the bonded substrate stack 101 is completely separated in about 2 min after the start of jet injection into the bonded substrate stack 101 (separation processing).

[Sixth Example of Substrate Holding Portion]

[0089] Figs. 18 and 19 are views showing the arrangement of substrate holding portions according to the sixth example of the present invention. Fig. 18 is a perspective view, and Fig. 19 is a front view. Substrate holding portions 132 and 162 shown in Figs. 18 and 19 are examples of the substrate holding portions 120 and 150 shown in Fig. 2, respectively.

[0090] The substrate holding portions 132 and 162 of this example have cross-shaped (radial) contact portions 132a and 162a which come into contact with the bonded substrate stack 101, on main bodies 132b and 162b, respectively. With the substrate holding portions 132 and 162, the bonded substrate stack 101 can deflect and corrugate forming "nodes" at a portion sandwiched by the contact portions 132a and 162a, so the separation force efficiently acts on the bonded substrate stack 101. In addition, since the jet medium discharge path is ensured, the jet medium pressure can be prevented from excessively increasing inside the bonded substrate stack 101. Therefore, the bonded substrate stack 101 can be prevented from breaking because of a portion of the porous layer, where the mechanical strength is locally high and separation progresses slowly.

[0091] With the use of the substrate holding portions 132 and 162, the bonded substrate stack 101 is completely separated in about 80 sec after the start of jet injection into the bonded substrate stack 101 (separation processing).

[0092] Figs. 20 to 24 are perspective views showing modifications of the substrate holding portions shown in Fig. 19. These substrate holding portions are examples of the substrate holding portions 120 and 150 shown in

Fig. 2.

[0093] Substrate holding portions 133 and 163 shown in Fig. 20 have star-shaped contact portions 133a and 163a which come into contact with the bonded substrate stack 101, on main bodies 133b and 163b, respectively. Substrate holding portions 134 and 164 shown in Fig. 21 also have star-shaped contact portions 134a and 164a which come into contact with the bonded substrate stack 101, on main bodies 134b and 164b, respectively. Substrate holding portions 135 and 165 shown in Fig. 22 have, on main bodies 135b and 165b, contact portions 135a and 165a which come into contact with the bonded substrate stack 101, respectively. Each of the contact portions 135a and 165a is separated into four parts at its central portion and form a cross. A substrate holding portion 136 shown in Fig. 23 has columnar contact portions 136a which come into contact with the bonded substrate stack 101, on a main body 136b. A substrate holding portion 1.66 has the same arrangement as that of the substrate holding portion 136. Substrate holding portions 137 and 167 shown in Fig. 24 have radial contact portions 137a and 167a which come into contact with the bonded substrate stack 101, on main bodies 137b and 167b, respectively.

[Comparative Example not falling within the scope of the invention claimed]

[0094] When this separating apparatus is to be applied to manufacture a semiconductor substrate such as the above-described SOI substrate, pure water or ultrapure water with minimum impurity metals or particles is preferably used as a jet medium. However, if the substrate is to be cleaned after separation, water having low purity may be used as a jet medium.

[0095] The jet medium is not limited to water. It is possible to use an organic solvent such as an alcohol, an acid such as fluoric acid or nitric acid, an alkali such as potassium hydroxide, a gas such as air, nitrogen gas, carbonic acid gas, rare gas, or an etching gas, or a plasma.

[0096] In this separating apparatus, a jet is ejected to the porous layer (separation region) exposed to the side surface of the bonded substrate stack, thereby removing the porous layer from the peripheral portion to the central portion. With this process, the bonded substrate stack is separated into two substrates by removing only the separation region with low mechanical strength without damaging the main body. Even when the side surface of the bonded substrate stack is covered with some thin layer, and the porous layer is not exposed, the thin layer can be removed by the jet, so the bonded substrate stack can be separated by the above-described method.

[0097] At the outer peripheral portion of the bonded substrate stack, a V-shaped (concave) groove is preferably formed along the side surface. Figs. 25A and 25B are views showing a force acting on the bonded substrate stack. Fig. 25A shows a bonded substrate stack having a V-shaped groove 22. Fig. 25B shows a bonded substrate stack having no V-shaped groove.

[0098] As shown in Fig. 25A, in the bonded substrate stack having the V-shaped groove 22, a force (to be referred to as a separation force hereinafter) is applied outward from the center of the bonded substrate stack, as indicated by an arrow 23. On the other hand, as shown in Fig. 25B, in the bonded substrate stack with a convex side surface, a force is applied inward from the side surface of the bonded substrate stack, as indicated by an arrow 24. In the bonded substrate stack having a convex side surface, the separation force does not act unless the side surface of a porous layer 12 as the separation region is removed by a jet 21.

[0099] Even when a thin film is formed on the side surface of the bonded substrate stack, the separation force acts on the bonded substrate stack as far as the bonded substrate stack has the V-shaped groove 22, as shown in Flog. 25A, so the thin layer can be easily broken.

[0100] To effectively use the jet, a width W1 of the V-shaped groove 22 is preferably equal to or larger than a diameter d of the jet 21. For example, assume that each of a first substrate (10) and a second substrate (20) has a thickness of about 1 mm, and the bonded substrate stack has a thickness of about 2 mm. Since the width W1 of the V-shaped groove 22 is normally around 1 mm, the diameter of the jet is preferably 1 mm or less. Since a general water jet apparatus uses a jet with a diameter around 0.1 to 0.5 mm, such a general water jet apparatus (e.g., a water jet nozzle) can be used.

[0101] The nozzle for ejecting a jet can have not only a circular shape but any other shapes. For example, when a slit-like nozzle is employed to eject a jet having a long rectangular section, the jet can be efficiently injected into the separation region (inserted between the two substrates).

[0102] The jet ejection conditions are determined in accordance with the type of separation region (e.g., a porous layer) or the shape of the side surface of the bonded substrate stack. Important parameters as the jet ejection conditions are the pressure applied to the jet medium, the jet scanning speed, the width or diameter of the nozzle (the nozzle diameter is almost the same as the jet diameter), the nozzle shape, the distance between the nozzle and the separation region, and the flow rate of the jet medium.

[0103] The following techniques are used to separate the bonded substrate stack. 1) The jet is injected into the bonding interface parallel to the bonding interface while the nozzle is scanned along the bonding interface. 2) The jet is injected into the bonding interface parallel to the bonding interface while the bonded substrate stack is scanned. 3) The jet is injected into the bonding interface parallel to the bonding interface and simultaneously scanned in a fan shape at a pivot near the nozzle. 4) The jet is injected into the bonding interface parallel to the bonding interface while the bonded substrate stack is rotated about nearly the center of the bonded

substrate stack (this technique is particularly effective when the bonded substrate stack has a disk shape). The jet need not always be ejected to be perfectly parallel to the bonding interface.

[0104] The bonded substrate stack is separated not only when the pore walls break by the cutting force, i.e., the impact force of the jet colliding against the pore walls in the porous layer but also when the pore walls break by the pressure of jet medium injected into the porous layer. To prevent damages to the substrate, the separation force acting in the axial direction of the bonded substrate stack is preferably set to be several hundred gf /cm^2.

[0105] To separate the bonded substrate stack using only the cutting force of jet, the jet must be ejected at a high pressure of 1,000 kg/cm^2 or more. If the bonded substrate stack is separated by such a high-pressure jet, the substrate may be damaged. The thickness of the bonded substrate stack is preferably about 0.5 to 1.0 mm. However, when such a thin bonded substrate stack is to be separated by a high-pressure jet, and the porous layer locally has portions with high strength, the jet pressure (separation force) may abruptly increase to break the substrate because the discharge path of the jet medium is not ensured.

[0106] Preferably, a jet with a low pressure of approximately 500 kgf/cm^2 is used, and the shortage of cutting force is compensated for by the separation force. With this method, damages to the substrate can be prevented at a relatively high ratio.

[0107] However, to prevent damages to the substrate, the shape or characteristics of the member to be separated is preferably taken into consideration. For example, when the bonded substrate stack is to be separated to the first substrate (10') side and the second substrate (10" + 20) side, the bonded substrate stack holding method in separation processing is preferably optimized in consideration of the shape or characteristics (especially, the strength) of the substrates. More specifically, the first substrate (10) is formed through various processes (including high-temperature process) such as anodizing, formation of an epitaxial layer, and oxidation and therefore readily breaks as compared to the second substrate (20). If the substrate is used again as the first substrate (10) by removing the porous layer remaining on the surface of the first substrate after separation, the first substrate becomes thinner by about 30 μm every time an SOI substrate is manufactured. For this reason, as the number of times of reuse increases, the first substrate breaks during separation processing with higher probability.

[0108] In this example, a separating apparatus is disclosed, in which the deflection amount by the separation force of the jet is made small for one of members to be separated, which has low strength and readily breaks, to prevent the member from breaking, and the deflection amount by the separation force of the jet is made large for a member which has high strength and hardly breaks to increase the efficiency of discharging the jet medium from the separation region (inside the member).

[Arrangement of Separating Apparatus]

[0109] A specific arrangement of the separating apparatus in the comparative example not falling within the scope of the invention claimed will be described below with reference to Figs. 26 to 28.

[0110] The separating apparatus of this example is suitable to separate a bonded substrate stack having a porous layer or microcavity layer as an internal fragile structure. This separating apparatus can also be used to separate another member having an internal fragile structure. In this case, the building elements of the separating apparatus must obviously be appropriately modified in accordance with the shape of the member to be separated.

[0111] Fig. 26 is a view schematically showing the arrangement of the separating apparatus according to the comparative example. Fig. 27 is a perspective view showing part of the separating apparatus shown in Fig. 26. Fig. 28 is a view schematically showing separation processing.

[0112] A separating apparatus 2000 has substrate holding portions 2120 and 2130 having vacuum chuck mechanisms. A bonded substrate stack 101 is sandwiched by the substrate holding portions 2120 and 2130 and held. The substrate holding portion 2120 comes into contact with the bonded substrate stack 101 in a large area. The substrate holding portion 2130 comes into contact with the bonded substrate stack 101 in a small area. With this structure, the deflection amount becomes small or no deflection occurs on one side of the bonded substrate stack 101 while the deflection amount in separation processing is made relatively large on the other side.

[0113] The bonded substrate stack 101 has a porous layer 101b as an internal fragile structure and is separated into a first substrate 101a and a second substrate 101c at the porous layer 101b by the separating apparatus 2000. The first substrate 101a corresponds to the above-described first substrate (10'), and the second substrate 101c corresponds to the above-described second substrate (10" + 20).

[0114] As described above, the first substrate 101a is formed through various processes (including high-temperature process) such as anodizing, formation of an epitaxial layer, and oxidation and therefore readily breaks as compared to the second substrate 101c. Therefore, when the first substrate 101a of the bonded substrate stack 101 is held by the substrate holding portion 2120 having a large-area holding surface, deflection of the first substrate 101a can be limited during separation processing and prevented from breaking. The second substrate 101c has a strength higher than that of the first substrate 101a and can withstand relatively large deflection. When the second substrate 101c is

held by the substrate holding portion 2130 having a small-area holding surface, the substrate 101c can deflect to some extent in separation processing. With this structure, the jet medium injected between the substrates 101a and 101c can be efficiently discharged, and consequently, separation processing can be efficiently performed.

[0115] The substrate holding portion 2120 is coupled to one end of a rotary shaft 104 which is rotatably axially supported by a support base 109 through a bearing 108. The other end of the rotary shaft 104 is coupled to the rotary shaft of a motor 110. The rotational force generated by the motor 110 rotates the bonded substrate stack 101. The motor 110 rotates the rotary shaft 104 at a designated rotation speed in accordance with an instruction from a controller (not shown).

[0116] The substrate holding portion 2130 is coupled to one end of a rotary shaft 103 which is rotatably and slidably axially supported by the support base 109 through a bearing 111. The other end of the rotary shaft 103 is coupled to an air cylinder 112 fixed on the support base 109. When the air cylinder 112 pushes the rotary shaft 103, the bonded substrate stack 101 is pressed by the substrate holding portion 2130.

[0117] To limit the deflection amount of the first substrate 101a to an amount as small as possible, the diameter of the chucking surface of the substrate holding portion 2120 is preferably made equal to or larger than the diameter of the bonded substrate stack 101, and additionally, the chucking surface is preferably made flat to support the entire surface of the first substrate 101a. However, the shape of the chucking surface of the substrate holding portion 2120 is not limited to this. The chucking surface may be a curved surface such as a spherical surface or have a smaller area than the bonded substrate stack 101. That is, the shape of the chucking surface of the substrate holding portion 2120 is determined in accordance with the allowable deflection amount of the first substrate 101a.

[0118] On the other hand, the shape of the chucking surface of the substrate holding portion 2130 is determined within the allowable deflection amount range of the second substrate 101c such that the deflection amount of the second substrate 101c becomes larger than that of the first substrate 101a.

[0119] The substrate holding portions 2120 and 2130 are present on the same rotary axis. The substrate holding portions 2120 and 2139 can be detached from the rotary shafts 104 and 103, respectively. The substrate holding portions 2120 and 2130 have vacuum chucking grooves on their holding surfaces. These grooves communicate with vacuum lines extending through the rotary shafts 104 and 103, respectively. These vacuum lines are coupled to external vacuum lines through, e.g., rotary vacuum joints. The external vacuum lines have solenoid valves. By controlling the solenoid valves, setting/removal of the substrate stack can be controlled.

[0120] Substrate separation processing using this separating apparatus 2000 will be described below.

[0121] To set the bonded substrate stack 101 in the separating apparatus 2000, first, the rotary shaft 103 is retracted by the air cylinder 112 to set a predetermined interval between the holding surfaces of the substrate holding portions 2120 and 2130. After the bonded substrate stack 101 is mounted on an alignment shaft 113, the air cylinder 112 pushes the rotary shaft 103, so the bonded substrate stack 101 is pressed and held (the state shown in Fig. 26). The alignment shaft 113 is rotatably axially supported through bearings 105 and 107.

[0122] In this example, the bonded substrate stack 101 is held not by vacuum chucking but by the pressing force of the air cylinder 112. The pressing force is preferably about 100 to 2000gf. The bonded substrate stack 101 may be vacuum-chucked, as a matter of course.

[0123] A jet medium (e.g., water) is sent from a pump 114 to a jet nozzle 102, and processing waits until the jet ejected from the jet nozzle 102 stabilizes. When the jet stabilizes, a shutter 106 is opened to inject the jet into the separation region of the bonded substrate stack 101, and at the same time, the bonded substrate stack 101 is rotated by the motor 110. At this time, the rotary shaft 104, substrate holding portion 2120, bonded substrate stack 101, substrate holding portion 2130, and rotary shaft 103 integrally rotate. The jet nozzle 102 is attached to a position adjustment mechanism (e.g., an X-Y stage), so the position from which the jet is injected into the bonded substrate stack 101 can be adjusted by the position adjustment mechanism.

[0124] When the jet is injected, a separation force due to the pressure of jet medium continuously injected into the porous layer 101b as a fragile structure acts on the bonded substrate stack 101 to break the porous layer 101b which connects the substrates 101a and 101c. At this time, the substrates 101a and 101c deflect in the allowable ranges of the substrate holding portions 2120 and 2130. In this separating apparatus 2000, the deflection amount of the substrate 101a is relatively small, and that of the substrate 101c is relatively large.

[0125] With this processing, the bonded substrate stack 101 is separated into two substrates in about 2 min.

[0126] When the bonded substrate stack 101 is separated into two substrates, the shutter 106 is closed, and the operation of pump 114 is stopped. By stopping rotation of the motor 110 and controlling the above-described electromagnetic valves, the separated substrates 101a and 101c are vacuum-chucked by the substrate holding portions 2120 and 2130.

[0127] When the air cylinder 112 retracts the rotary shaft 103, the surface tension of the jet medium (e.g., water) is cut off to split the two physically separated substrates 101a and 101c to both sides.

[0128] Modifications of the substrate holding portion of the separating apparatus 2000 will be described next.

[A Modification]

[0129] In the separating apparatus of this modification, the substrate.holding portions 2120 and 2130 of the separating apparatus 2000 shown in Figs. 26 to 28 are replaced with each other. Fig. 29 is a view showing the schematic arrangement of a separating apparatus 2000' of this modification.

[0130] In this separating apparatus 2000', the substrate holding portion 2120 holds the first substrate 101a side of the bonded substrate stack 101, and the substrate holding portion 2130 holds the second substrate 101c. That is, in the separating apparatus 2000', the bonded substrate stack 101 is held such that the second substrate 101c is positioned on the side of the rotary shaft 104 whose horizontal position is fixed.

[0131] This separating apparatus 2000' is suitable to reuse the first substrate 101a after separation as the first substrate (10) by removing the porous layer 101b remaining on the surface of the substrate 101a. The reason for this is as follows.

[0132] When the first substrate 101a is to be reused, the first substrate 101a becomes thinner in accordance with the number of times of reuse. For this reason, when separation processing is to be efficiently and appropriately performed in the separating apparatus 2000 shown in Fig. 26, the jet nozzle 102 must be located immediately above the separation region of the bonded substrate stack 101 for every separation processing. If the position of the jet nozzle 102 is fixed, the jet may not be injected into the center of the porous layer 101b to damage the substrates 101a and 101c.

[0133] However, in the separating apparatus 2000' of this modification, as far as the bonded substrate stack 101 whose second substrate 101c has a predetermined thickness is to be processed, the positional relationship between the porous layer 101b and the jet nozzle 102 does not change even when the position of the jet nozzle 102 is fixed. This is because the position of the substrate holding portion 2130 is fixed, and the second substrate 101c held by the substrate holding portion 2130 has a predetermined thickness.

[Second Embodiment]

[0134] In the second embodiment of the invention, the structure of each substrate holding portion of the separating apparatus 2000 shown in Figs. 26 to 28 is modified. Fig. 30 is a view showing the schematic arrangement of the substrate holding portions of the separating apparatus of this embodiment. In this separating apparatus, a substrate holding portion 2121 having an almost circular chucking surface holds the first substrate 101a side of the bonded substrate stack 101, and a substrate holding portion 2131 having an almost annular chucking surface holds the second substrate 101c side of the bonded substrate stack 101.

[0135] The substrate holding portions 2121 and 2131 of this embodiment limit the deflection amounts of the first substrate 101a and that of the second substrate 101c in the allowable deflection amount ranges, respectively, and increase the efficiency of separation processing while preventing damages to the substrates 101a and 101c.

[0136] Since the diameter of the substrate holding portion 2121 is smaller than the bonded substrate stack 101, the first substrate 101a deflects while warping at its outer peripheral portion in separation processing. The holding surface of the substrate holding portion 2121 may be a flat surface or a curved surface such as a spherical surface. On the other hand, since the substrate holding portion 2131 has an annular holding surface, the substrate 101c deflects while corrugating forming "nodes" near the chucking surface (701 and 702 in Fig. 30) and "antinodes" at the outer peripheral portion and central portion. When the substrate holding portions 2121 and 2131 with shapes allowing the second substrate 101c to deflect while corrugating are employed, the jet medium injected into the bonded substrate stack 101 can be efficiently discharged.

[0137] Separation processing was executed using this separating apparatus. After the jet was injected into the bonded substrate stack 101, the jet proceeded to the holding surface (701 in Fig. 30) of the substrate holding portion 2131 in about 30 sec. After this, the jet proceeded to the holding surface (702 in Fig. 30) on the opposite side after about 30 sec, and the substrate 101c deflected while corrugating, as shown in Fig. 30. The bonded substrate stack 101 was separated into two substrates in about 3 min.

[0138] In separation processing of the bonded substrate stack 101, the jet medium is hardly discharged at the central portion of bonded substrate stack. For this reason, the pressure of the jet medium readily increases, so the central portion is easily damaged as compared to the peripheral portion. Hence, when only the second substrate 101c with high strength is allowed to deflect while expanding to the substrate holding portion 2131 side at its central portion, as in the substrate holding portions of this modification, the discharge path of the jet medium can be ensured while preventing damages to the first substrate 101a with low strength.

[A Modification]

[0139] In a modification of the second embodiment of the invention, the structures of the substrate holding portions 2120 and 2130 of the separating apparatus 2000 shown in Figs. 26 to 28 are modified. Fig. 31 is a view showing a modification of the substrate holding portion 2120 for holding the first substrate side. Fig. 32 is a view showing a modification of the substrate holding portion 2130 for holding the second substrate side.

[0140] As shown in Fig. 31, a substrate holding portion 2122 for holding the first substrate 101a side has a diameter slightly smaller than that of the bonded sub-

strate stack 101 and a flat chucking surface. Therefore, the first substrate 101a deflects while warping at its outer peripheral portion in separation processing.

[0141] On the other hand, as shown in Fig. 32, a substrate holding portion 2132 has a plurality of projecting chuck portions 2132a. The second substrate 101c side of the bonded substrate stack 101 is held by the tips of the plurality of chuck portions 2132a. When the second substrate 101c side is held by the projecting suction portions 2132a, the substrate 101c can easily deflect, and the jet medium injected into the bonded substrate stack 101 can be efficiently discharged. To stably hold the bonded substrate stack 101, the number of projecting chuck portions 2132a is preferably three or more.

Claims

1. A method of separating a plate-like sample (101) at an internal fragile layer (101b), said method comprising the steps of:

    holding the sample (101) between respective contact portions of two opposing holding portions (120, 150) so as to sandwich the sample; and
    ejecting a fluid towards said fragile layer at the edge of the sample so as to inject fluid into the sample, thereby separating the sample,

    characterized in that:
    said contact portions are configured so as to cause a face of the held sample to become corrugated during the step of ejecting the fluid.

2. A method of separating a plate-like sample according to claim 1, further including the step of rotating the two holding portions (120, 150) about shafts (103, 104) perpendicular to the holding surfaces so as to rotate the sample.

3. A method of separating a plate-like sample according to either of claims 1 and 2, wherein the fragile layer (101b) is a porous Si-layer (12) formed by anodizing or an ion-implanted microcavity layer formed by ion implantation.

4. A method of separating a plate-like sample according to any of claims 1 or 2, wherein the sample to be separated is a sample formed by bonding first and second substrates (10, 20) having different strengths.

5. A method of separating a plate-like sample according to any of claims 1 to 4, wherein water is used as the ejected fluid.

6. A method of manufacturing a substrate, the method comprising the steps of:

    sequentially forming a porous layer (12) and a non-porous layer (13) on a first substrate to produce a first composite slab (10);
    forming an insulating layer (15) on a second substrate (14) to produce a second composite slab (20);
    bringing said non-porous layer and said insulating layer into contact and bonding said first and second composite slabs to form a plate-like sample (101) in which said porous layer is an internal fragile layer (101b); and
    separating said plate-like sample at said porous layer by a method according to any of claims 1 to 5.

7. A support apparatus for supporting a plate-like sample (101), said support apparatus being adapted for use in a separating device (100) for separating said sample at an internal fragile layer (101b) by the pressure of fluid ejected from a jet unit (102) provided in said separating device and injected into said sample (101), said support apparatus having two opposing holding portions (120, 150) for holding respective opposing faces of the sample so as to sandwich the sample, the two holding portions having a contact portion for contacting a first part of a face of the sample so as to prevent substantial deflection of said first part of said face of the sample and being **characterized by**:

    said at least one of the two holding portions having a contact portion comprising a raised portion (121a, 122a, 123a, 124a, 125a, 126a) surrounding a non-contact hollow portion for allowing deflection of a second part of said face of the sample,
    wherein said opposing portions are configured so as to allow a face of the held sample to become corrugated under the pressure of fluid ejected from said jet unit.

8. A support apparatus for supporting a plate-like sample (101), said support apparatus being adapted for use in a separating device (100) for separating said sample at an internal fragile layer (101b) by the pressure of fluid ejected from a jet unit (102) provided in said separating device and injected into said sample (101), said support apparatus having two opposing holding portions (120, 150) for holding respective opposing faces of the sample so as to sandwich the sample, the two holding portions having a contact portion for contacting a first part of a face of the sample so as to prevent substantial deflection of said first part of said face of the sample and being **characterized by**:

    said at least one of the two holding portions having a multiplicity of contact portions (126a, 127a, 128a, 129a, 129c, 131a, 135a, 136a, 2132a) and a

non-contact portion for allowing deflection of a second part of said face of the sample,

wherein said opposing portions are configured so as to allow a face of the held sample to become corrugated under the pressure of fluid ejected from said jet unit.

9. A support apparatus for supporting a plate-like sample (101), said support apparatus being adapted for use in a separating device (100) for separating said sample at an internal fragile layer (101b) by the pressure of fluid ejected from a jet unit (102) provided in said separating device and injected into said sample (101), said support apparatus having two opposing holding portions (120, 150) for holding respective opposing faces of the sample so as to sandwich the sample, the two holding portions having a contact portion for contacting a first part of a face of the sample so as to prevent substantial deflection of said first part of said face of the sample and being **characterized by**:

said at least one of the two holding portions having a radial contact portion (132a, 133a, 134a, 137a) and a non-contact portion for allowing deflection of a second part of said face of the sample,

wherein said opposing portions are configured so as to allow a face of the held sample to become corrugated under the pressure of fluid ejected from said jet unit.

10. A support apparatus according to any of claims 7 to 9, wherein the first and second holding portions (121, 151) form a symmetrical pair, such that in use the contact portion (121a) of the first holding portion is positioned opposite a respective contact portion (151a) of the second holding portion.

11. A support apparatus according to either claim 7 or claim 8, wherein the contact portion of the first holding portion (2131, 2132) differs in size or shape from the contact portion of the second holding portion (2121, 2122).

12. A support apparatus according to claim 11, wherein the contact portion of the second holding portion (2121, 2122) comprises a flat surface.

13. A support apparatus according to claim 7, wherein the first holding portion (121,151) has a contact portion comprising concentric raised portions (126a, 126b) surrounding an annular hollow portion.

14. A support apparatus according to claim 7, wherein the first holding portions has one or a plurality of strip-shaped contact portions (122a, 123a).

15. A support apparatus according to claim 8, wherein the first holding portion (127, 157) has one or a plurality of arcuate contact portions (127a, 157a).

16. A support apparatus according to claim 8, wherein the first holding portion has a plurality of projecting contact portions (128a, 131a, 135a, 2132a) on a main body surface thereof, whereby the sample can be held by the tips of said plurality of projecting contact portions.

17. A support apparatus according to any of claims 7 to 16, wherein the first holding portion has a contact portion (138a, 168a) adapted to come into contact with a peripheral portion of the sample.

18. A support apparatus according to claim 17, wherein said contact portion (138a, 168a) is adapted to contact the whole peripheral portion of the sample.

19. A support apparatus according to any of claims 7 to 18, further comprising a limit portion (138b, 168b) for limiting the deflection of a face of the sample when said fluid is injected into the sample.

20. A support apparatus according to any of claims 7 to 19, further comprising an adjustment mechanism (112) for adjusting the distance between the holding portions (120, 150).

21. A support apparatus according to claim 20, wherein said adjustment mechanism (112) is operable to press the sample to adjust the distance between the holding portions (120, 150).

22. A support apparatus according to either claim 20 or 21, wherein said adjustment mechanism (112) is operable to maintain a substantially constant distance between the holding portions (120, 150).

23. A support apparatus according to any of claims 7 to 22, wherein each holding portion (120, 150) has a chuck mechanism (181, 182) for vacuum-chucking the sample.

24. A support apparatus according to any of claims 7 to 23, further comprising a rotation mechanism (110) for rotating at least one of the first and second holding portions (120, 150) about a shaft (104) perpendicular to the holding surfaces so as to rotate the sample.

25. A support apparatus according to any of claims 7 to 24, adapted to hold a sample which comprises a substrate having a porous layer (12) as the fragile layer (101b).

26. A support apparatus according to claim 25, wherein the fragile layer (101b) is a porous layer (12) formed by anodizing or an ion-implanted layer formed by

ion implantation.

27. A support apparatus according to any of claims 7 to 26, adapted to hold a sample formed by bonding first and second substrates (10, 20) having different strengths.

28. A separating device (100) for separating a plate-like sample (101) at an internal fragile layer (101b), said separating apparatus comprising:

a jet unit (102) for ejecting a fluid towards said fragile layer in the direction of the thickness the sample; and
a support apparatus for supporting the sample in the path of said fluid, said support apparatus having the features recited in any of claims 7 to 24.

Patentansprüche

1. Verfahren zum Trennen einer plättchenförmigen Probe (101) an einer inneren zerbrechlichen Schicht (101b), wobei das Verfahren folgende Schritte aufweist:

Halten der Probe (101) zwischen jeweiligen Kontaktabschnitten von zwei gegenüberliegenden Halteabschnitten (120, 150), um die Probe zwischenzuklemmen; und

Ausstoßen einer Flüssigkeit in Richtung auf die zerbrechliche Schicht an der Kante der Probe, um Flüssigkeit in die Probe einzuspritzen, wobei die Probe getrennt wird,

dadurch gekennzeichnet, daß:
die Kontaktabschnitte konfiguriert werden, um zu bewirken, daß eine Seitenfläche der gehaltenen Probe während des Schrittes des Ausstoßens der Flüssigkeit gewellt wird.

2. Verfahren zum Trennen einer plättchenförmigen Probe nach Anspruch 1, ferner einschließlich des Schritts des Rotierens der zwei Halteabschnitte (120, 150) um einen senkrecht zu den Halteoberflächen verlaufenden Schaft (103, 104), um die Probe zu rotieren.

3. Verfahren zum Trennen einer plättchenförmigen Probe nach einem der Ansprüche 1 und 2, wobei die zerbrechliche Schicht (101b) eine durch Anodisieren gebildete poröse Si-Schicht (12) oder eine durch Ionenimplantation gebildete ionenimplantierte Mikrohohlraum-Schicht ist.

4. Verfahren zum Trennen einer plättchenförmigen Probe nach einem der Ansprüche 1 oder 2, wobei die zu trennende Probe eine durch Verbinden erster und zweiter Substrate (10, 20) mit verschiedenen Stärken gebildete Probe ist.

5. Verfahren zum Trennen einer plättchenförmigen Probe nach einem der Ansprüche 1 bis 4, wobei Wasser als die ausgestoßene Flüssigkeit verwendet wird.

6. Verfahren zur Herstellung eines Substrats, wobei das Verfahren die folgenden Schritte aufweist:

sequentielles Ausbilden einer porösen Schicht (12) und einer nichtporösen Schicht (13) auf einem ersten Substrat, um eine erste Verbundplatte (10) zu erzeugen;
Ausbilden einer Isolationsschicht (15) auf einem zweiten Substrat (14), um eine zweite Verbundplatte (20) zu erzeugen;
in Kontakt Bringen der nichtporösen Schicht und der Isolationsschicht und Verbinden der ersten und zweiten Verbundplatte, um eine plättchenförmige Probe (101) auszubilden, in welcher die poröse Schicht eine innere zerbrechliche Schicht (101b) ist; und
Trennen der plättchenförmigen Probe an der porösen Schicht durch ein Verfahren nach einem der Ansprüche 1 bis 5.

7. Trägervorrichtung zum Tragen einer plättchenförmigen Probe (101), wobei die Trägervorrichtung geeignet ist zum Gebrauch in einer Trennungseinrichtung (100) zum Trennen der Probe an einer inneren zerbrechlichen Schicht (101b) durch den Druck einer Flüssigkeit, die von einer in der Trennungseinrichtung vorgesehenen Strahleinheit (102) ausgestoßen wird und in die Probe (101) eingespritzt wird, und in die Probe (101) eingespritzt wird, wobei die Trägervorrichtung zwei gegenüberliegende Halteabschnitte (120, 150) zum Halten jeweils gegenüberliegender Seitenflächen der Probe aufweist, um die Probe zwischenzuklemmen, wobei die zwei Halteabschnitte einen Kontaktabschnitt zum Kontaktieren eines ersten Teils einer Seitenfläche der Probe aufweisen, um eine wesentliche Durchbiegung des ersten Teils der Seitenfläche der Probe zu verhindern, und **dadurch gekennzeichnet ist, daß**: zumindest einer der zwei Halteabschnitte einen Kontaktabschnitt aufweist, der einen erhöhten Abschnitt (121a, 122a, 123a, 124a, 125a, 126a) aufweist, der einen nichtkontaktierenden Hohlabschnitt umschließt, um eine Durchbiegung eines zweiten Teils der Seitenfläche der Probe zuzulassen,
wobei die gegenüberliegenden Abschnitte konfiguriert sind, um einer Seitenfläche der gehaltenen Probe zu erlauben, unter dem Druck der von der

Strahleinheit ausgestoßenen Flüssigkeit gewellt zu werden.

8. Trägervorrichtung zum Tragen einer plättchenförmigen Probe (101), wobei die Trägervorrichtung geeignet ist zum Gebrauch in einer Trennungseinrichtung (100) zum Trennen der Probe an einer inneren zerbrechlichen Schicht (101b) durch den Druck einer Flüssigkeit, die von einer in der Trennungseinrichtung vorgesehenen Strahleinheit (102) ausgestoßen wird und in die Probe (101) eingespritzt wird, wobei die Trägervorrichtung zwei gegenüberliegende Halteabschnitte (120, 150) zum Halten von jeweils gegenüberliegenden Seitenflächen der Probe aufweist, um die Probe zwischenzuklemmen, wobei die zwei Halteabschnitte einen Kontaktabschnitt zum Kontaktieren eines ersten Teils einer Seitenfläche der Probe aufweisen, um eine wesentliche Durchbiegung des ersten Teils der Seitenfläche der Probe zu verhindern, und **dadurch gekennzeichnet ist, daß**:

   zumindest einer der zwei Halteabschnitte eine Vielfalt von Kontaktabschnitten (126a, 127a, 128a, 129a, 129c, 131a, 135a, 136a, 2132a) und einen nichtkontaktierenden Abschnitt aufweist, um eine Durchbiegung eines zweiten Teils der Seitenfläche der Probe zuzulassen,

   wobei die gegenüberliegenden Abschnitte konfiguriert sind, um einer Seitenfläche der gehaltenen Probe zu erlauben, unter dem Druck der von der Strahleinheit ausgestoßenen Flüssigkeit gewellt zu werden.

9. Trägervorrichtung zum Tragen einer plättchenförmigen Probe (101), wobei die Trägervorrichtung geeignet ist zum Gebrauch in einer Trennungseinrichtung (100) zum Trennen der Probe an einer inneren zerbrechlichen Schicht (101b) durch den Druck einer Flüssigkeit, die von einer in der Trennungseinrichtung vorgesehenen Strahleinheit (102) ausgestoßen wird und in die Probe (101) eingespritzt wird, wobei die Trägervorrichtung zwei gegenüberliegende Halteabschnitte (120, 150) zum Halten von jeweils gegenüberliegenden Seitenflächen der Probe aufweist, um die Probe zwischenzuklemmen, wobei die zwei Halteabschnitte einen Kontaktabschnitt zum Kontaktieren eines ersten Teils einer Seitenfläche der Probe aufweisen, um eine wesentliche Durchbiegung des ersten Teils der Seitenfläche der Probe zu verhindern, und **dadurch gekennzeichnet ist, daß**:

   zumindest einer der zwei Halteabschnitte einen radialen Kontaktabschnitt (132a, 133a, 134a, 137a) und einen nichtkontaktierenden Abschnitt aufweist, um eine Durchbiegung eines zweiten Teils der Seitenfläche der Probe zuzulassen,

   wobei die gegenüberliegenden Abschnitte konfiguriert sind, um einer Seitenfläche der gehaltenen Probe zu erlauben, unter dem Druck der von der Strahleinheit ausgestoßenen Flüssigkeit gewellt zu werden.

10. Trägervorrichtung nach einem der Ansprüche 7 bis 9, wobei der erste und zweite Halteabschnitt (121, 151) ein symmetrisches Paar bilden, so daß bei Gebrauch der Kontaktabschnitt (121a) des ersten Halteabschnitts gegenüber einem jeweiligen Kontaktabschnitts (151a) des zweiten Halteabschnitts angeordnet ist.

11. Trägervorrichtung entweder nach Anspruch 7 oder Anspruch 8, wobei sich der Kontaktabschnitt des ersten Halteabschnitts (2131, 2132) in Größe oder Form von dem Kontaktabschnitt des zweiten Halteabschnitts (2121, 2122) unterscheidet.

12. Trägervorrichtung nach Anspruch 11, wobei der Kontaktabschnitt des zweiten Halteabschnitts (2121, 2122) eine flache Oberfläche aufweist.

13. Trägervorrichtung nach Anspruch 7, wobei der erste Halteabschnitt (121, 151) einen Kontaktabschnitt aufweist, der konzentrisch erhöhte Abschnitte (126a, 126b) aufweist, die einen ringförmigen Hohlabschnitt umschließen.

14. Trägervorrichtung nach Anspruch 7, wobei die ersten Halteabschnitte einen oder eine Vielzahl von streifenförmigen Kontaktabschnitten (122a, 123a) aufweisen.

15. Trägervorrichtung nach Anspruch 8, wobei der erste Halteabschnitt (127, 157) einen oder eine Vielzahl von gekrümmten Kontaktabschnitten (127a, 157a) aufweist.

16. Trägervorrichtung nach Anspruch 8, wobei der erste Halteabschnitt eine Vielzahl von vorstehenden Kontaktabschnitten (128a, 131a, 135a, 2132a) auf dessen Hauptkörperoberfläche aufweist, wobei die Probe durch die Enden der Vielzahl von vorstehenden Kontaktabschnitten gehalten werden kann.

17. Trägervorrichtung nach einem der Ansprüche 7 bis 16, wobei der erste Halteabschnitt einen Kontaktabschnitt (138a, 168a) aufweist, der geeignet ist, mit einem Umfangsabschnitt der Probe in Kontakt zu kommen.

18. Trägervorrichtung nach Anspruch 17, wobei der Kontaktabschnitt (138a, 168a) geeignet ist, den ge-

samten Umfangsabschnitt der Probe zu kontaktieren.

19. Trägervorrichtung nach einem der Ansprüche 7 bis 18, ferner mit einem Begrenzungsabschnitt (138b, 168b) zum Begrenzen der Durchbiegung einer Seitenfläche der Probe, wenn die Flüssigkeit in die Probe eingespritzt wird.

20. Trägervorrichtung nach einem der Ansprüche 7 bis 19, ferner mit einem Einstellmechanismus (112) zum Einstellen des Abstands zwischen den Halteabschnitten (120, 150).

21. Trägervorrichtung nach Anspruch 20, wobei der Einstellmechanismus (112) betätigbar ist, um die Probe zu drücken, um den Abstand zwischen den Halteabschnitten (120, 150) einzustellen.

22. Trägervorrichtung entweder nach Anspruch 20 oder 21, wobei der Einstellmechanismus (112) betätigbar ist, um einen im wesentlichen konstanten Abstand zwischen den Halteabschnitten (120, 150) aufrechtzuerhalten.

23. Trägervorrichtung nach einem der Ansprüche 7 bis 22, wobei jeder Halteabschnitt (120, 150) einen Einspannmechanismus (181, 182) zum Vakuum-Einspannen der Probe aufweist.

24. Trägervorrichtung nach einem der Ansprüche 7 bis 23, ferner mit einem Rotationsmechanismus (110) zum Rotieren von zumindest einem der ersten und zweiten Halteabschnitte (120, 150) um einen senkrecht zu den Halteoberflächen verlaufenden Schaft (104), um die Probe zu rotieren.

25. Trägervorrichtung nach einem der Ansprüche 7 bis 24, welche geeignet ist zum Halten einer Probe, die ein Substrat mit einer porösen Schicht (12) als zerbrechliche Schicht (101b) aufweist.

26. Trägervorrichtung nach Anspruch 25, wobei die zerbrechliche Schicht (101b) eine poröse Schicht (12), die durch Anodisieren gebildet ist, oder eine ionenimplantierte Schicht ist, die durch Ionenimplantation gebildet ist.

27. Trägervorrichtung nach einem der Ansprüche 7 bis 26, welche geeignet ist zum Halten einer Probe, die durch Verbinden erster und zweiter Substrate (10, 20) mit verschiedenen Stärken gebildet ist.

28. Trennungseinrichtung (100) zum Trennen einer plättchenförmigen Probe (101) an einer inneren zerbrechlichen Schicht (101b), wobei die Trennungseinrichtung folgendes aufweist:

eine Strahleinheit (102) zum Ausstoßen einer Flüssigkeit auf die zerbrechliche Schicht in der Richtung der Dicke der Probe; und
eine Trägervorrichtung zum Tragen der Probe in der Bahn der Flüssigkeit, wobei die Trägervorrichtung die in einem der Ansprüche 7 bis 24 aufgeführten Merkmale aufweist.

Revendications

1. Procédé pour séparer un échantillon (101) analogue à une plaque au niveau d'une couche interne fragile (101b), ledit procédé comprenant les étapes qui consistent :

à maintenir l'échantillon (101) entre des parties de contact respectives de deux parties opposées (120, 150) de maintien afin que l'échantillon soit serré entre elles ; et
à éjecter un fluide vers ladite couche fragile au bord de l'échantillon afin d'injecter du fluide dans l'échantillon, séparant ainsi l'échantillon,

caractérisé en ce que :
lesdites parties de contact sont configurées de façon à rendre ondulée une face de l'échantillon maintenu pendant l'étape d'éjection du fluide.

2. Procédé de séparation d'un échantillon analogue à une plaque selon la revendication 1, comprenant en outre l'étape consistant à faire tourner les deux parties de maintien (120, 150) autour d'arbres (103, 104) perpendiculaires aux surfaces de maintien afin de faire tourner l'échantillon.

3. Procédé de séparation d'un échantillon analogue à une plaque selon l'une des revendications 1 et 2, dans lequel la couche fragile (101b) est une couche (12) de Si poreux formée par anodisation ou une couche à microcavités implantée d'ions, formée par implantation d'ions.

4. Procédé de séparation d'un échantillon analogue à une plaque selon l'une des revendications 1 et 2, dans lequel l'échantillon devant être séparé est un échantillon formé en liant des premier et second substrats (10, 20) ayant des solidités différentes.

5. Procédé de séparation d'un échantillon analogue à une plaque selon l'une quelconque des revendications 1 à 4, dans lequel de l'eau est utilisée en tant que fluide éjecté.

6. Procédé de fabrication d'un substrat, le procédé comprenant les étapes qui consistent :

à former séquentiellement une couche poreuse

(12) et une couche non poreuse (13) sur un premier substrat pour produire une première lame composite (10) ;
à former une couche isolante (15) sur un second substrat (14) pour produire une seconde lame composite (20) ;
à amener ladite couche non poreuse et ladite couche isolante en contact et à lier lesdites première et seconde lames composites pour former un échantillon (101) analogue à une plaque dans lequel ladite couche poreuse est une couche interne fragile (101b) ; et
à séparer ledit échantillon analogue à une plaque au niveau de ladite couche poreuse par un procédé selon l'une quelconque des revendications 1 à 5.

7. Appareil de support destiné à supporter un échantillon (101) analogue à une plaque, ledit support étant conçu pour être utilisé dans un dispositif de séparation (100) destiné à séparer ledit échantillon au niveau d'une couche interne fragile (101b) par la pression d'un fluide éjecté depuis une unité à jet (102) située dans ledit dispositif de séparation et injecté dans ledit échantillon (101), ledit appareil de support ayant deux parties opposées (120, 150) de maintien destinées à maintenir des faces opposées respectives de l'échantillon afin que l'échantillon soit serré entre elles, les deux parties de maintien ayant une partie de contact destinée à entrer en contact avec une première portion d'une face de l'échantillon afin d'empêcher toute déformation substantielle de ladite première portion de ladite face de l'échantillon, et étant **caractérisé en ce que** :
ladite, au moins une, des deux parties de maintien a une partie de contact comportant une partie surélevée (121a, 122a, 123a, 124a, 125a, 126a) entourant une partie creuse sans contact pour permettre une déformation d'une seconde portion de ladite face de l'échantillon,
dans lequel lesdites parties opposées sont configurées de façon à permettre à une face de l'échantillon maintenu de devenir ondulée sous la pression du fluide éjecté de ladite unité à jet.

8. Appareil de support destiné à supporter un échantillon (101) analogue à une plaque, ledit appareil de support étant conçu pour une utilisation dans un dispositif de séparation (100) destiné à séparer ledit échantillon au niveau d'une couche interne fragile (101b) par la pression d'un fluide éjecté d'une unité à jet (102) situé dans ledit dispositif de séparation, et injecté dans ledit échantillon (101), l'appareil de support ayant deux parties opposées (120, 150) de maintien destinées à maintenir des faces opposées respectives de l'échantillon afin que l'échantillon soit serré entre elles, les deux parties de maintien ayant une partie de contact destinée à entrer en contact avec une première portion d'une face de l'échantillon afin d'empêcher toute déformation substantielle de ladite première portion de ladite face de l'échantillon et étant **caractérisé en ce que** :
ladite, au moins une, des deux parties de maintien a de multiples parties de contact (126a, 127a, 128a, 129a, 129c, 131a, 135a, 136a, 2132a) et une partie de non-contact pour permettre une déformation d'une seconde portion de ladite face de l'échantillon,
dans lequel lesdites parties opposées sont configurées de façon à permettre à une face de l'échantillon maintenu de devenir ondulée sous la pression du fluide éjecté de ladite unité à jet.

9. Appareil de support destiné à supporter un échantillon (101) analogue à une plaque, ledit appareil de support étant conçu pour une utilisation dans un dispositif de séparation (100) destiné à séparer ledit échantillon au niveau d'une couche interne fragile (101b) par la pression d'un fluide éjecté d'une unité à jet (102) située dans ledit dispositif de séparation, et injecté dans ledit échantillon (101), ledit appareil de support ayant deux parties opposées (120, 150) de maintien destinées à maintenir les faces opposées respectives de l'échantillon afin que l'échantillon soit serré entre elles, les deux parties de maintien ayant une partie de contact destinée à entrer en contact avec une première portion d'une face de l'échantillon afin d'empêcher toute déformation substantielle de ladite première portion de ladite face de l'échantillon et étant **caractérisé en ce que** :
ladite, au moins une, des deux parties de maintien a une partie radiale de contact (132a, 133a, 134a, 137a) et une partie de non-contact pour permettre une déformation d'une seconde portion de ladite face de l'échantillon,
dans lequel lesdites parties opposées sont configurées de façon à permettre à une face de l'échantillon maintenu de devenir ondulée sous l'effet de la pression d'un fluide éjecté de ladite unité à jet.

10. Appareil de support selon l'une quelconque des revendications 7 à 9, dans lequel les première et seconde parties de maintien (121, 151) forment une paire symétrique telle que, lors de l'utilisation, la partie de contact (121a) de la première partie de maintien est positionnée de façon à être opposée à une partie de contact respective (151a) de la seconde partie de maintien.

11. Appareil de support selon la revendication 7 ou la revendication 8, dans lequel la partie de contact de la première partie de maintien (2131, 2132) diffère en dimension ou en forme de la partie de contact de la seconde partie de maintien (2121, 2122).

12. Appareil de support selon la revendication 11, dans lequel la partie de contact de la seconde partie de maintien (2121, 2122) présente une surface plate.

13. Appareil de support selon la revendication 7, dans lequel la première partie de maintien (121, 151) a une partie de contact comprenant des parties surélevées concentriques (126a, 126b) entourant une partie annulaire creuse.

14. Appareil de support selon la revendication 7, dans lequel la première partie de maintien comporte une ou plusieurs parties de contact (122a, 123a) en forme de bande.

15. Appareil de support selon la revendication 8, dans lequel la première partie de maintien (127, 157) comporte une ou plusieurs parties courbes (127a, 157a) de contact.

16. Appareil de support selon la revendication 8, dans lequel la première partie de maintien comporte plusieurs parties (128a, 131a, 135a, 2132a) de contact en saillie sur une surface de corps principal de cette partie, grâce à quoi l'échantillon peut être maintenu par les extrémités desdites plusieurs parties de contact en saillie.

17. Appareil de support selon l'une quelconque des revendications 7 à 16, dans lequel la première partie de maintien comporte une partie de contact (138a, 168a) conçue pour venir en contact avec une partie périphérique de l'échantillon.

18. Appareil de support selon la revendication 17, dans lequel ladite partie de contact (138a, 168a) est conçue pour entrer en contact avec la partie périphérique entière de l'échantillon.

19. Appareil de support selon l'une quelconque des revendications 7 à 18, comportant en outre une partie de limitation (138b, 168b) destinée à limiter la déformation d'une face de l'échantillon lorsque ledit fluide est injecté dans l'échantillon.

20. Appareil de support selon l'une quelconque des revendications 7 à 19, comportant en outre un mécanisme de réglage (112) pour régler la distance entre les parties de maintien (120, 150).

21. Appareil de support selon la revendication 20, dans lequel ledit mécanisme de réglage (112) peut agir de façon à appliquer une pression à l'échantillon pour régler la distance entre les parties de maintien (120, 150).

22. Appareil de support selon la revendication 20 ou 21, dans lequel ledit mécanisme de réglage (112) peut agir de façon à maintenir une distance sensiblement constante entre les parties de maintien (120, 150).

23. Appareil de support selon l'une quelconque des revendications 7 à 22, dans lequel chaque partie de maintien (120, 150) comporte un mécanisme (181, 182) à plateau de serrage destiné à immobiliser par vide l'échantillon.

24. Appareil de support selon l'une quelconque des revendications 7 à 23, comportant en outre un mécanisme (110) de rotation destiné à faire tourner au moins l'une des première et seconde parties de maintien (120, 150) autour d'un arbre (104) perpendiculaire aux surfaces de maintien afin de faire tourner l'échantillon.

25. Appareil de support selon l'une quelconque des revendications 7 à 24, conçu pour maintenir un échantillon qui comporte un substrat ayant une couche poreuse (12) en tant que couche fragile (101b).

26. Appareil de support selon la revendication 25, dans lequel la couche fragile (101b) est une couche poreuse (12) formée par anodisation ou une couche implantée d'ions formée par implantation d'ions.

27. Appareil de support selon l'une quelconque des revendications 7 à 26, conçu pour maintenir un échantillon formé en liant des premier et second substrats (10, 20) ayant des solidités différentes.

28. Dispositif de séparation (100) destiné à séparer un échantillon (101) analogue à une plaque au niveau d'une couche interne fragile (101b), ledit appareil de séparation comportant :

une unité à jet (102) destinée à éjecter un fluide vers ladite couche fragile dans la direction de l'épaisseur de l'échantillon ; et
un appareil de support destiné à supporter l'échantillon dans la trajectoire dudit fluide, ledit appareil de support ayant les caractéristiques citées dans l'une quelconque des revendications 7 à 24.

FIG. 1A

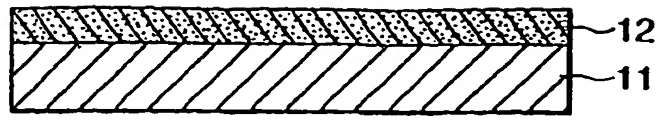


FIG. 1B

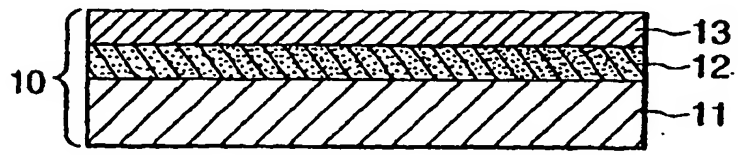


FIG. 1C

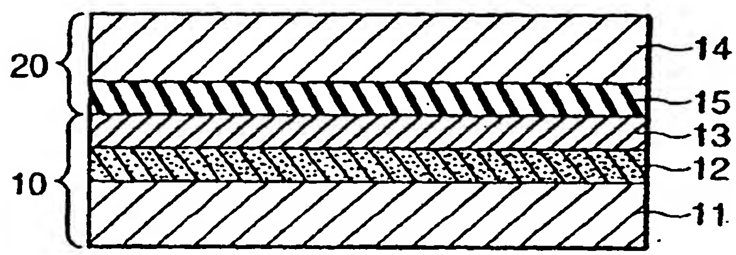


FIG. 1D

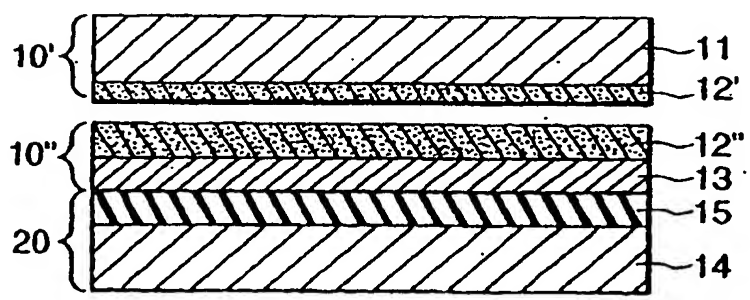


FIG. 1E

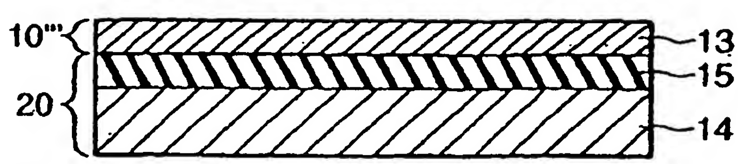


FIG. 2

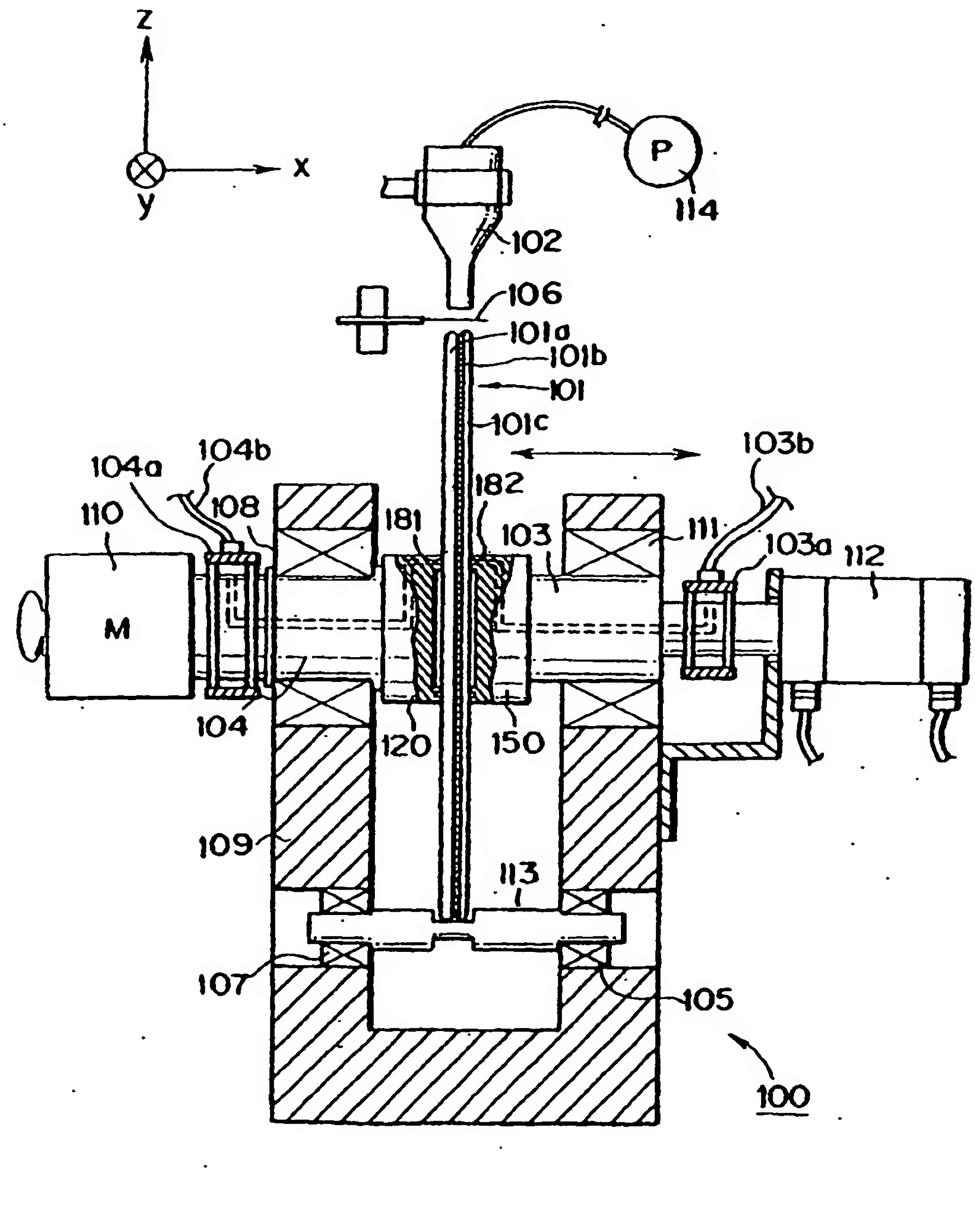

z
x
y
P
114
102
106
101a
101b
101
101c
104a
104b
110
108
182
181
103
111
103b
103a
112
M
104
120
150
109
113
107
105
100

FIG. 3

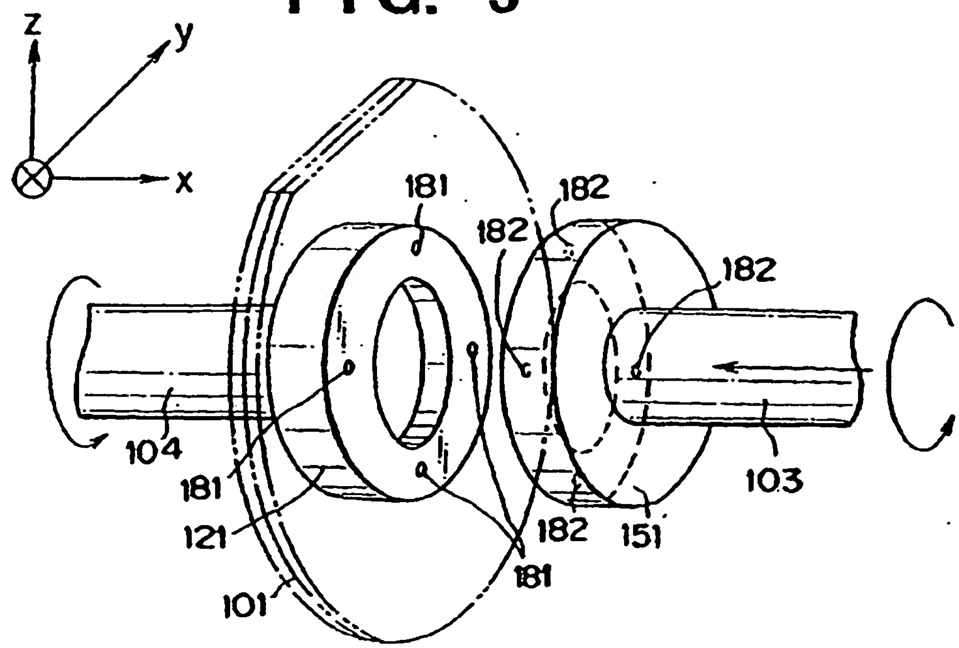

z
y
x
181
182
182
182
104
181
121
101
182
151
181
103

FIG. 4

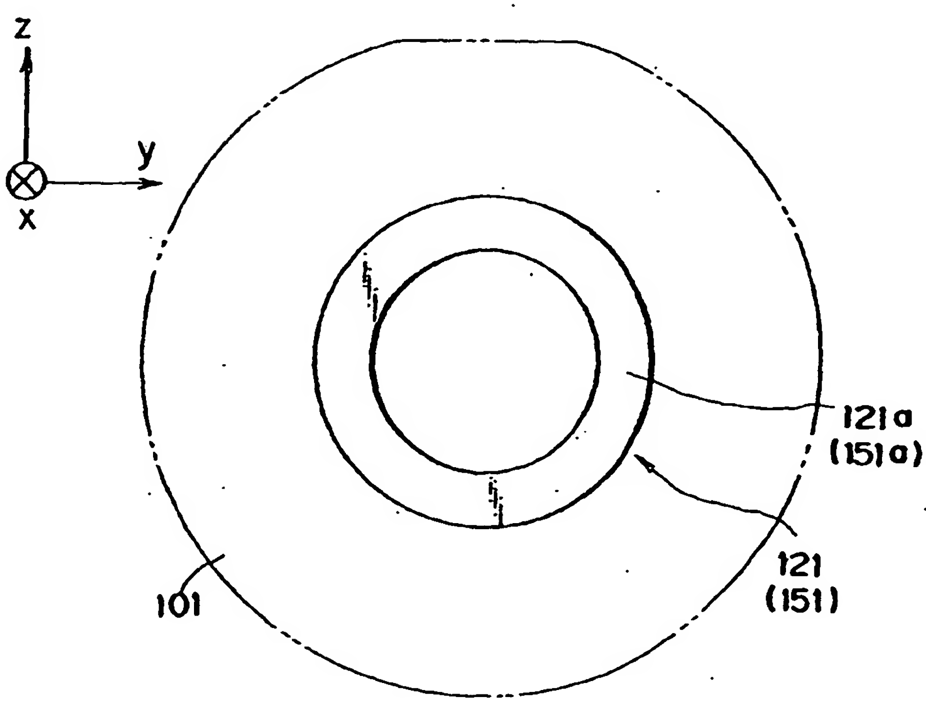

z
y
x
121a
(151a)
121
(151)
101

FIG. 5

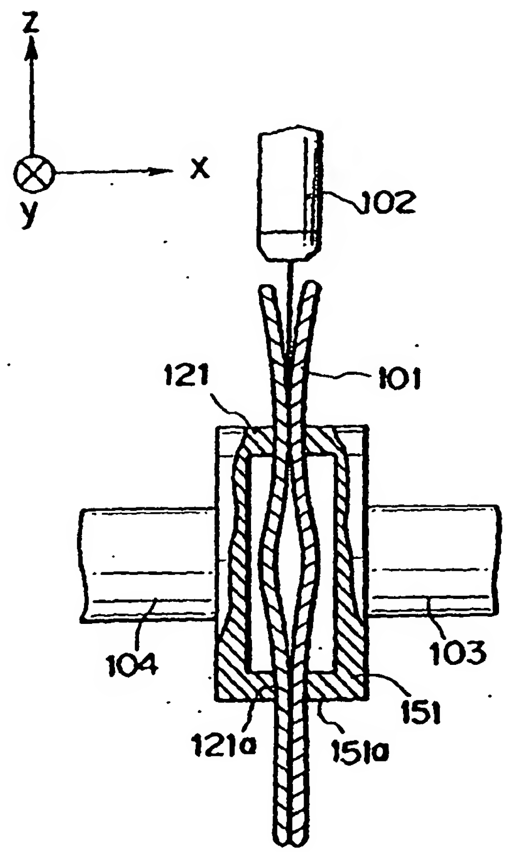


FIG. 6

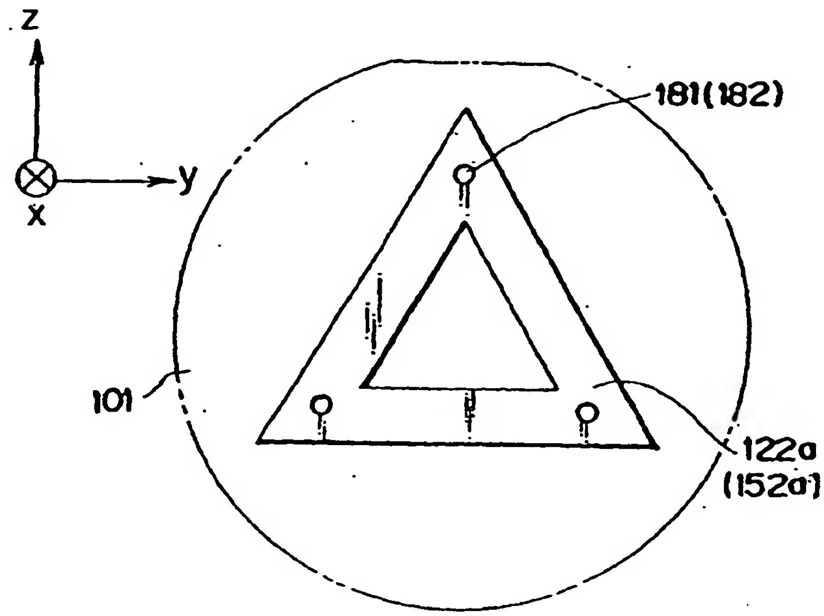


FIG. 7

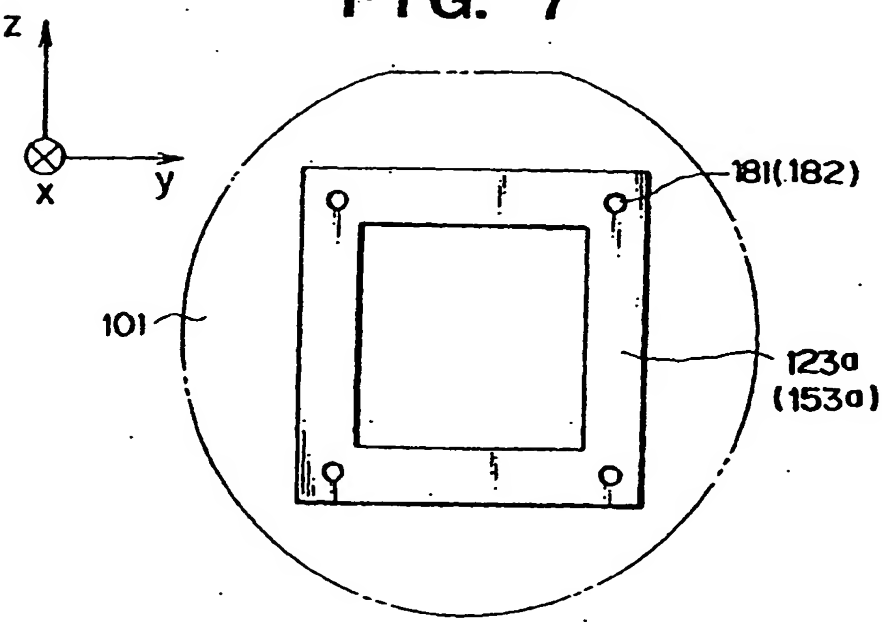


FIG. 8

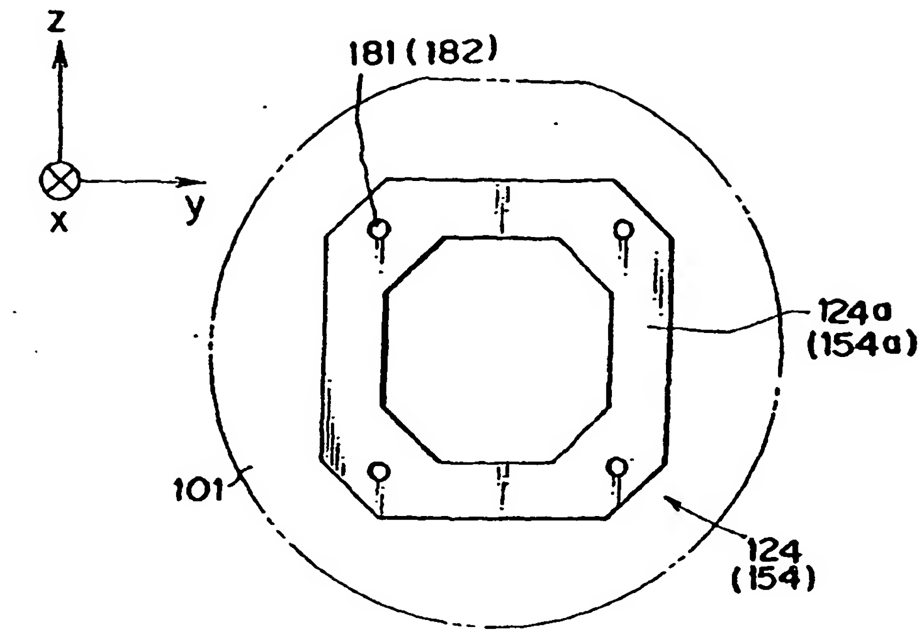

z
x
y
181 (182)
124a
(154a)
101
124
(154)

FIG. 9

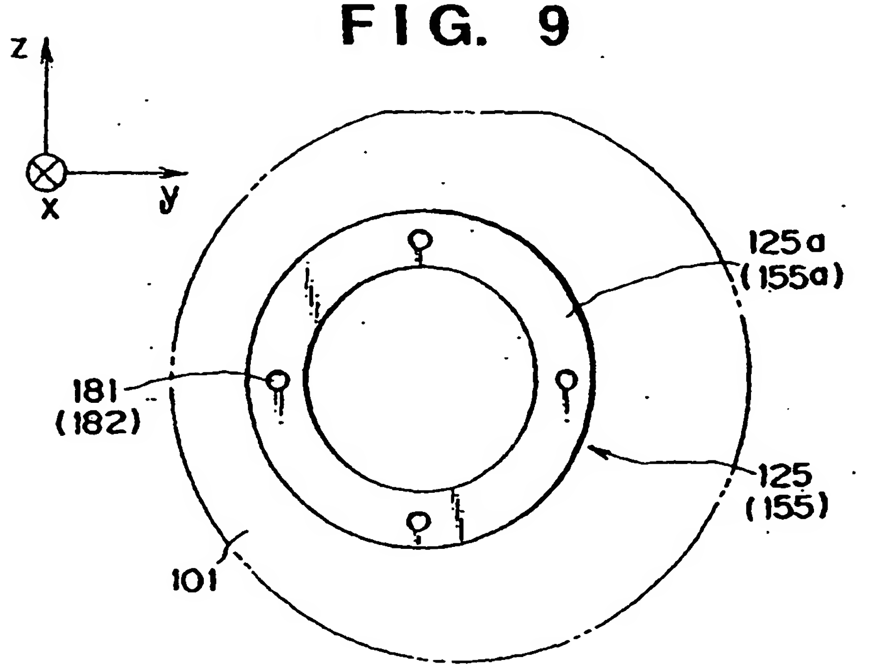

z
x
y
125a
(155a)
181
(182)
125
(155)
101

FIG. 10

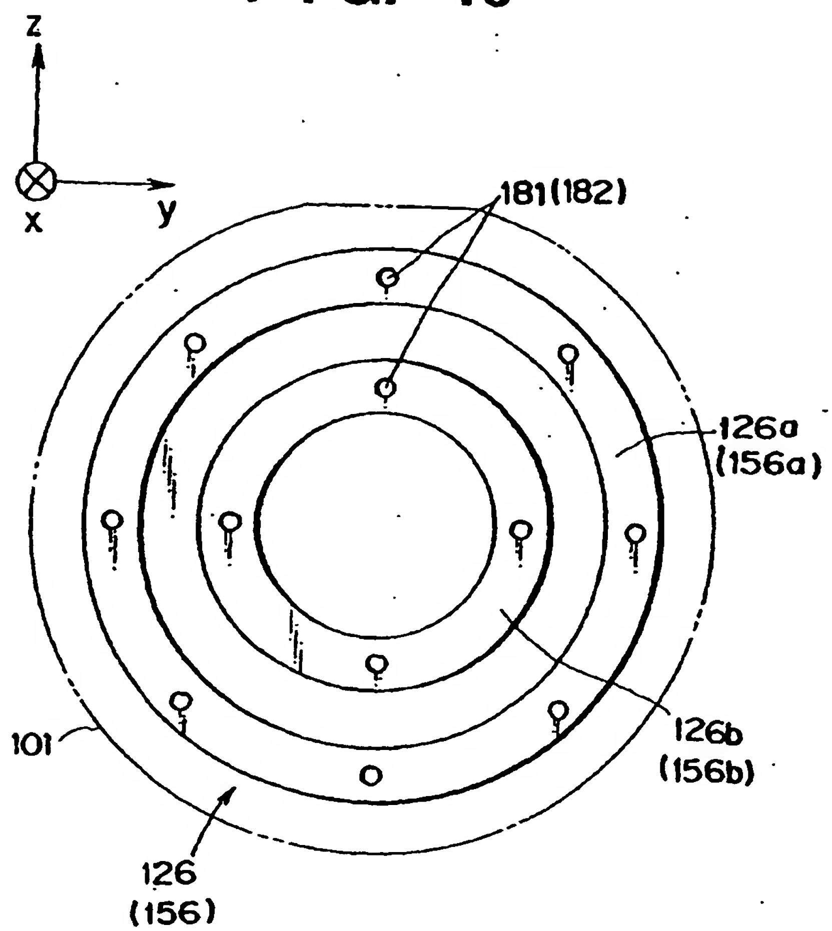


FIG. 11

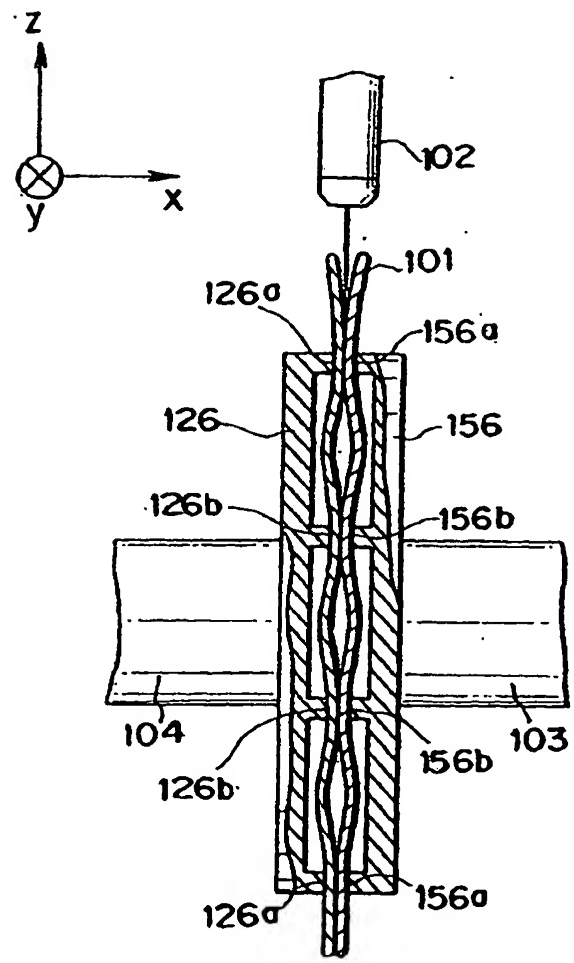

Z
X
y
102
101
126a
156a
126
156
126b
156b
104
103
126b
156b
126a
156a

FIG. 12

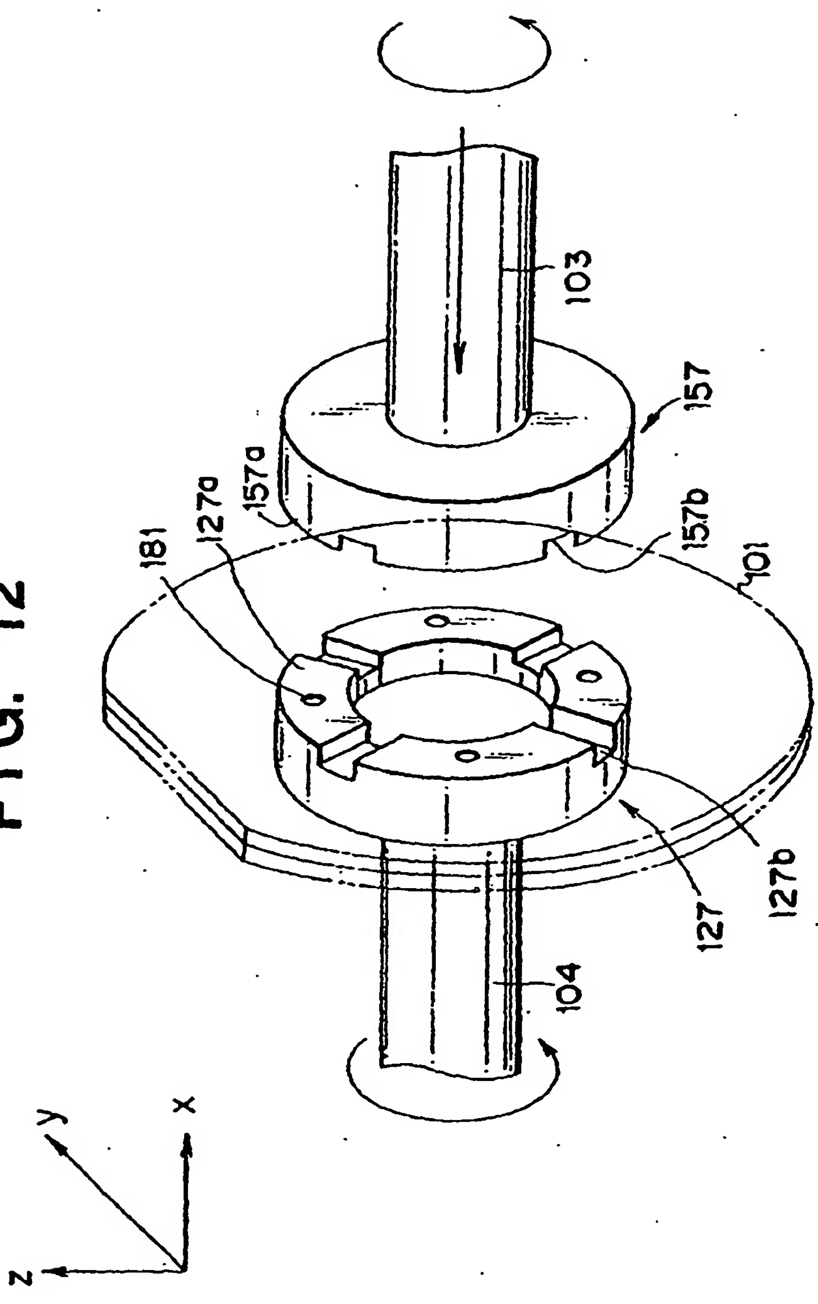


FIG. 13

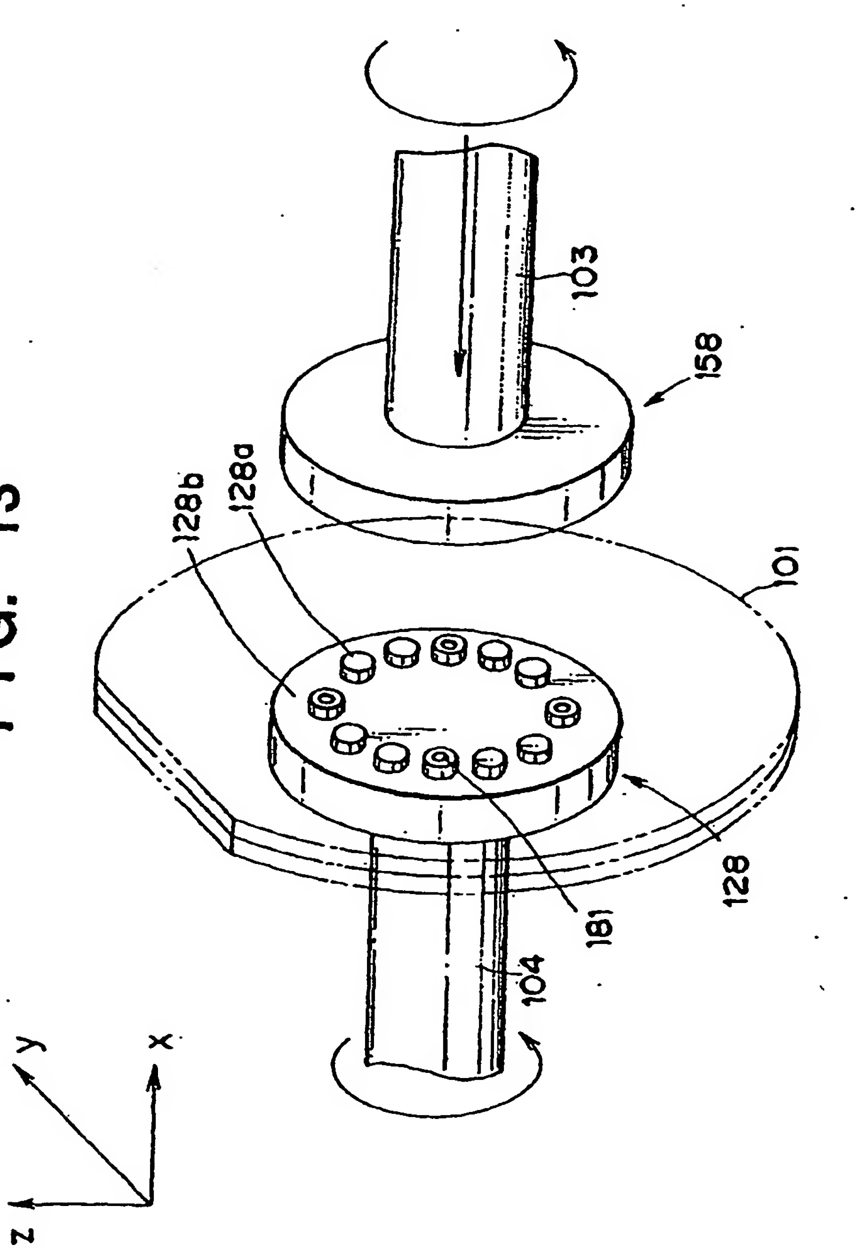


FIG. 14

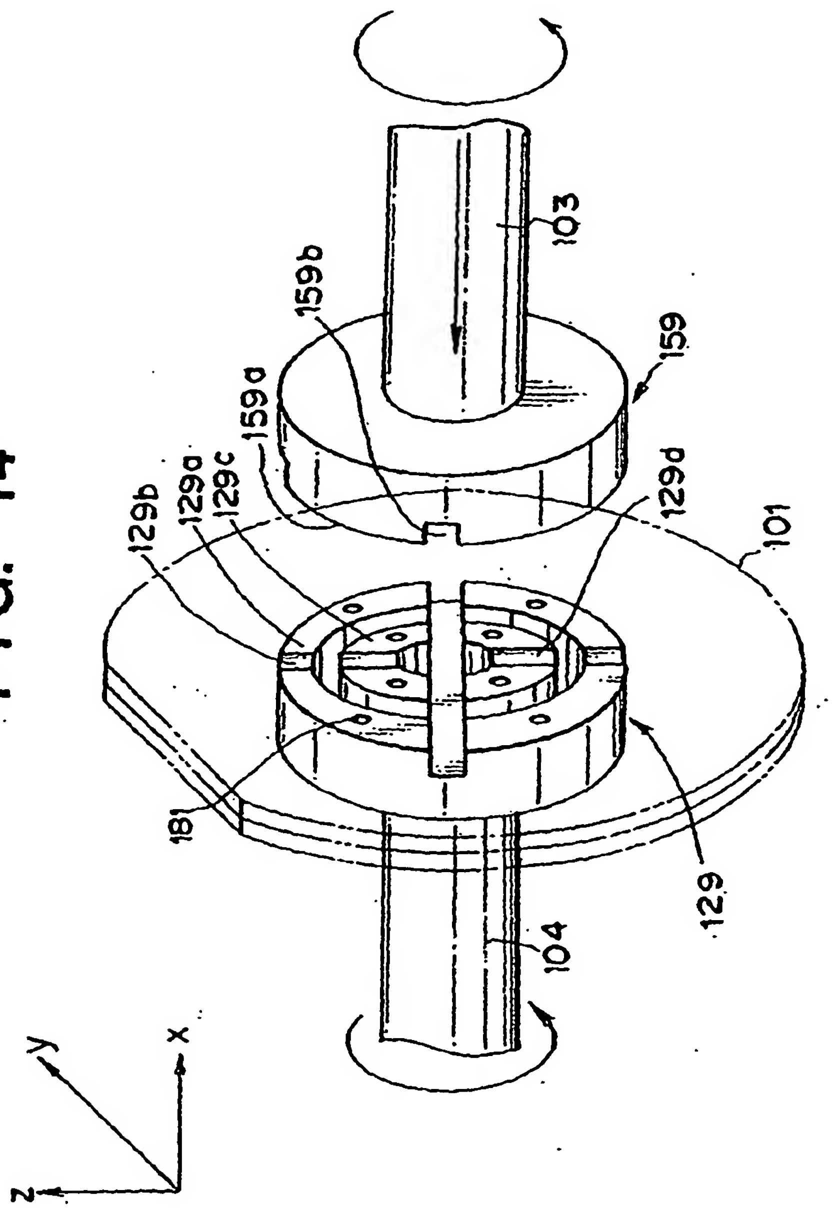


FIG. 15

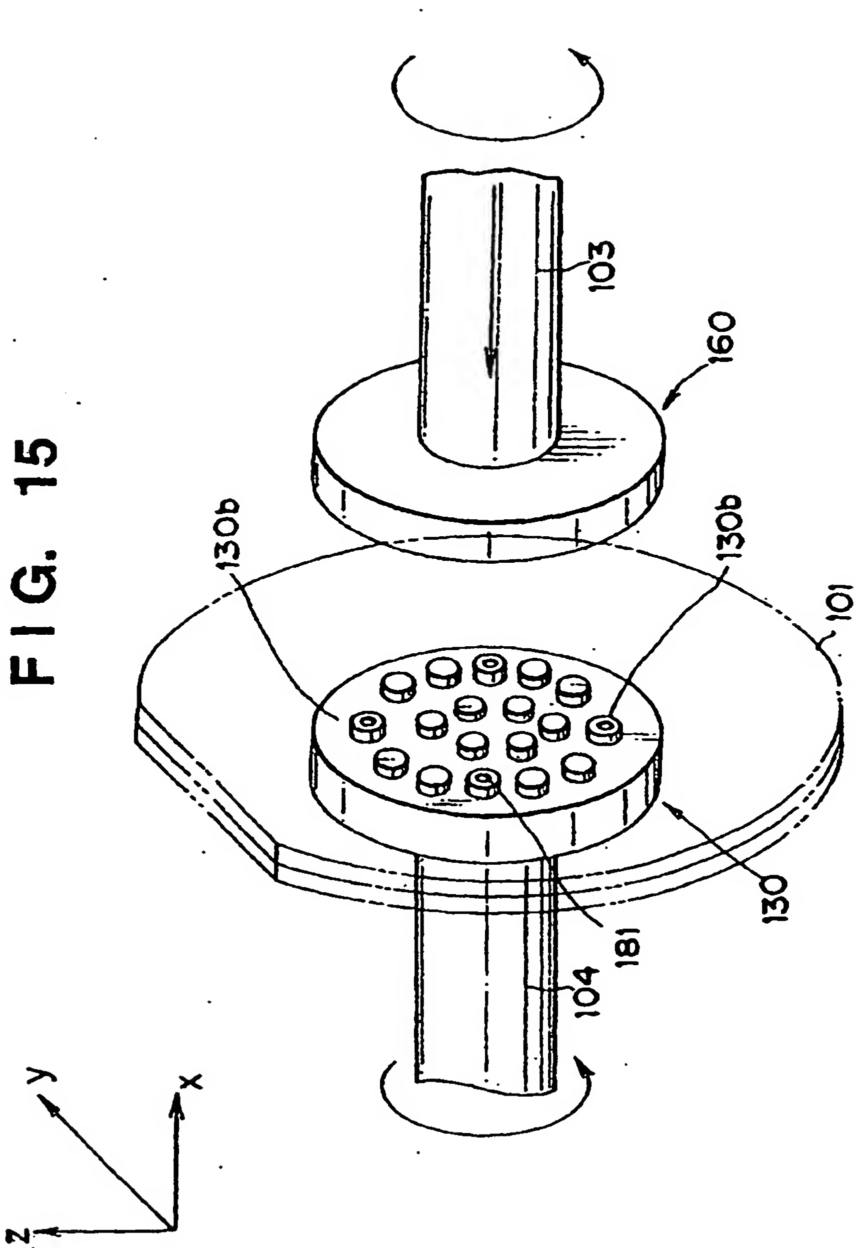


FIG. 16

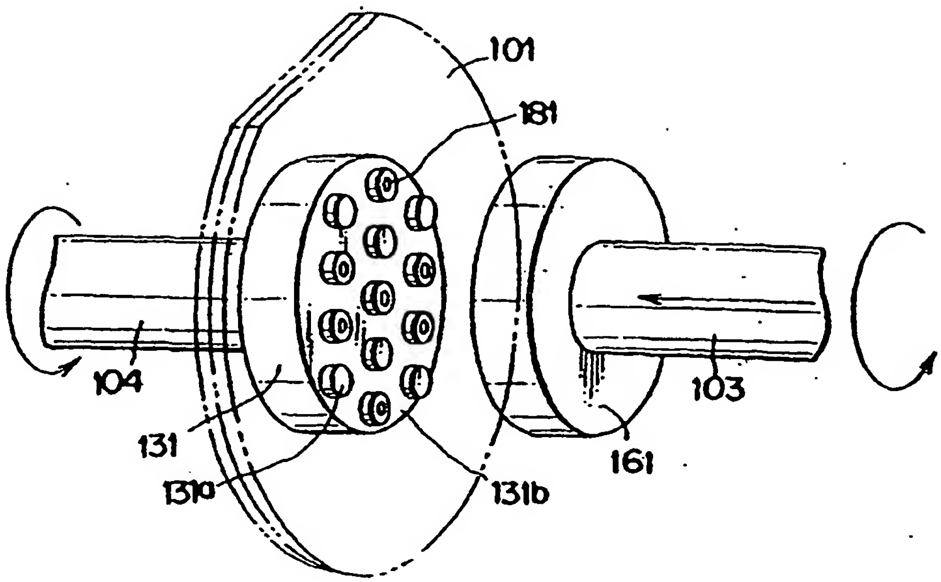

101
181
104
103
131
161
131a
131b

FIG. 17

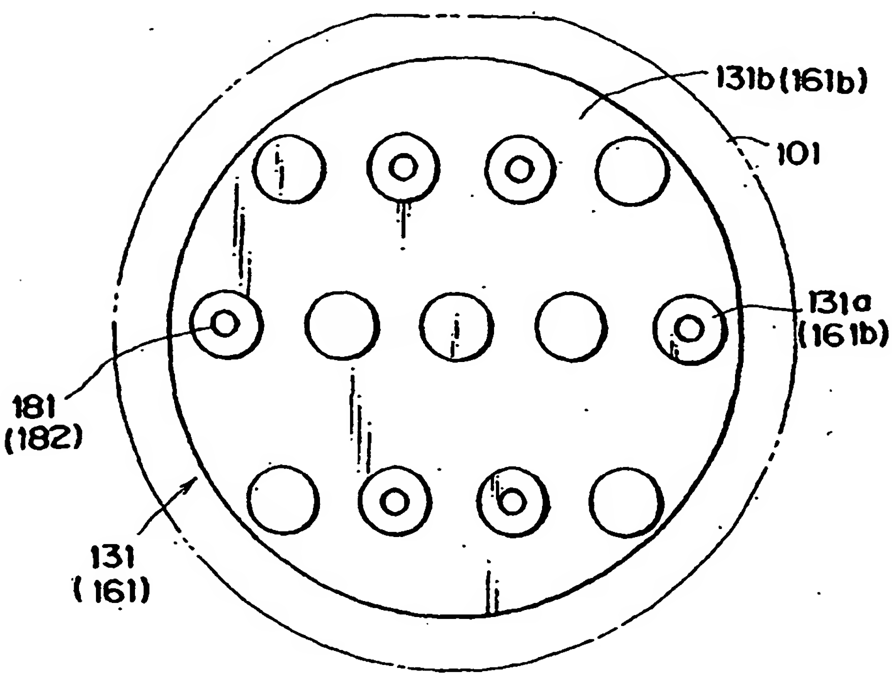

131b (161b)
101
131a
(161b)
181
(182)
131
(161)

FIG. 18

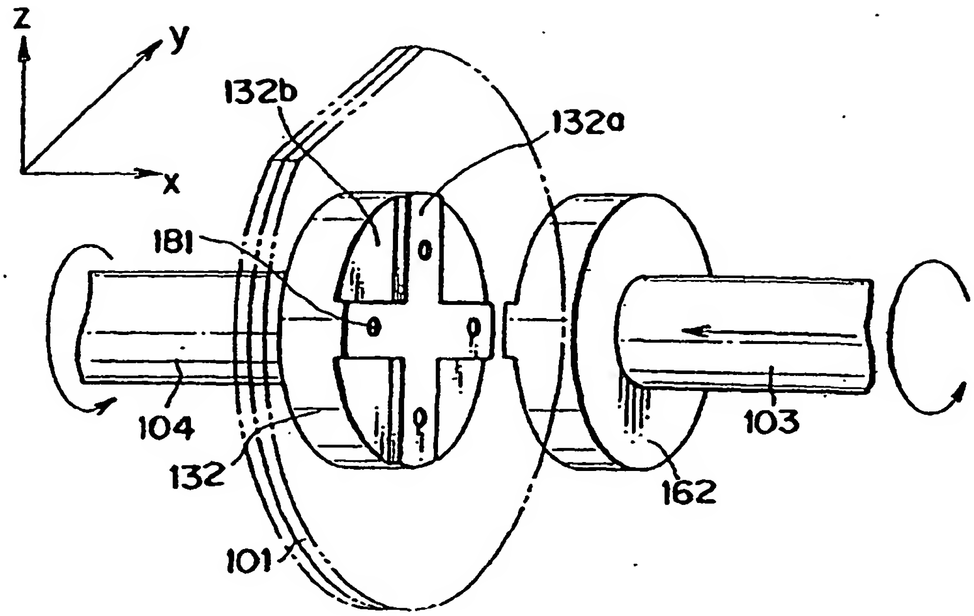

z
y
x
132b
132a
181
104
103
132
162
101

FIG. 19

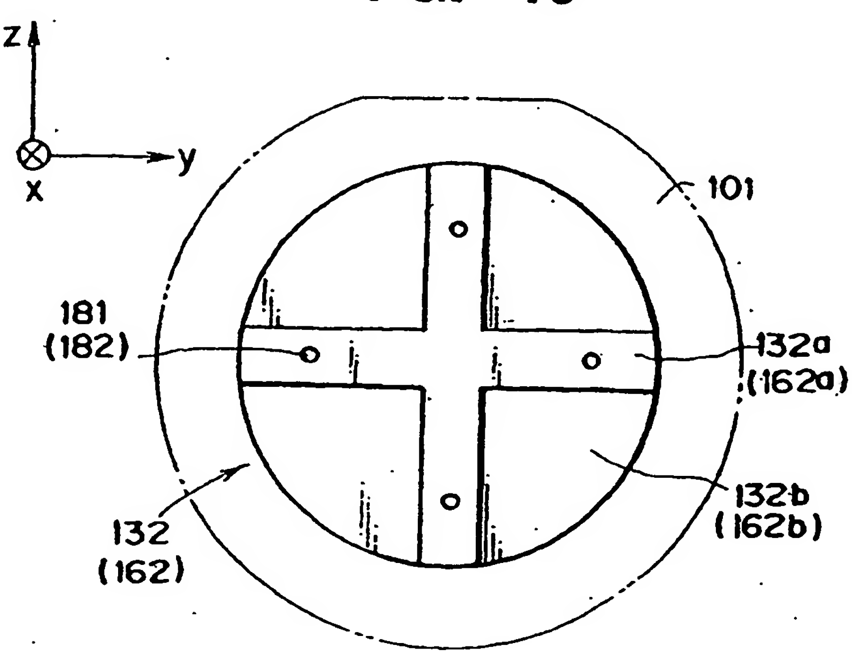

z
y
x
101
181
(182)
132a
(162a)
132b
(162b)
132
(162)

FIG. 20

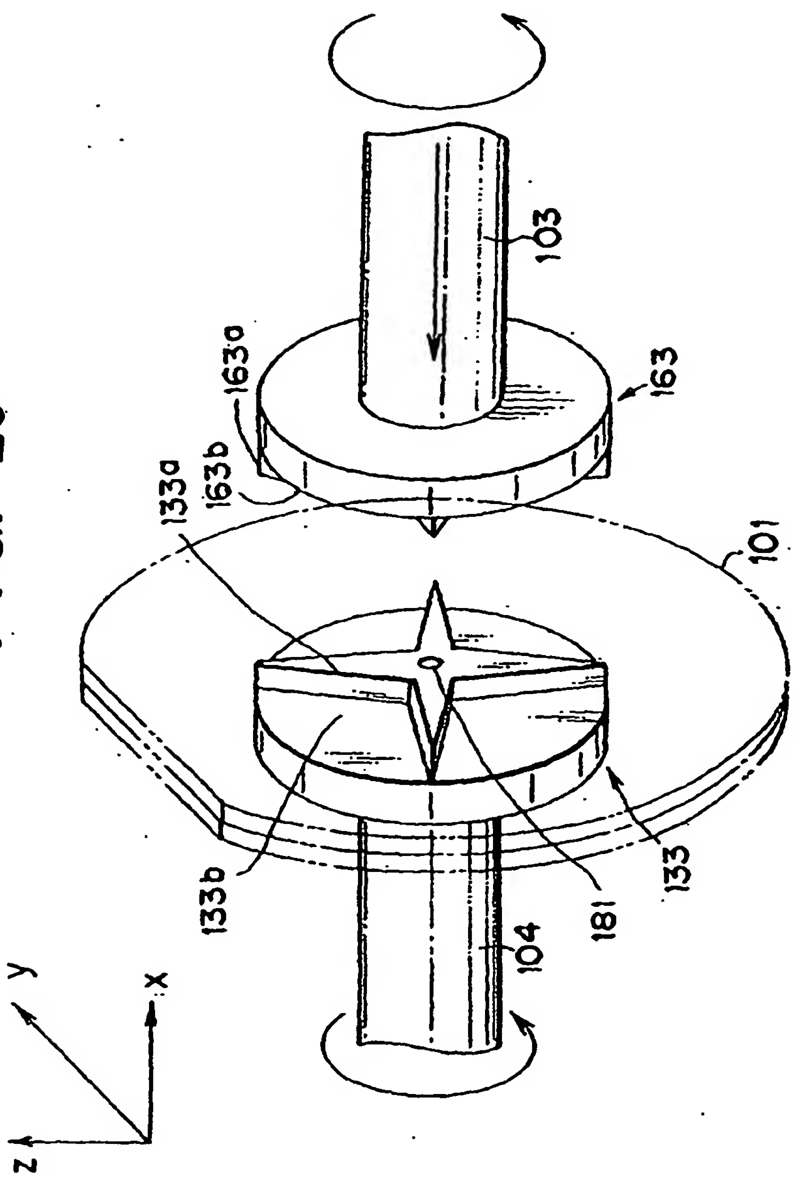
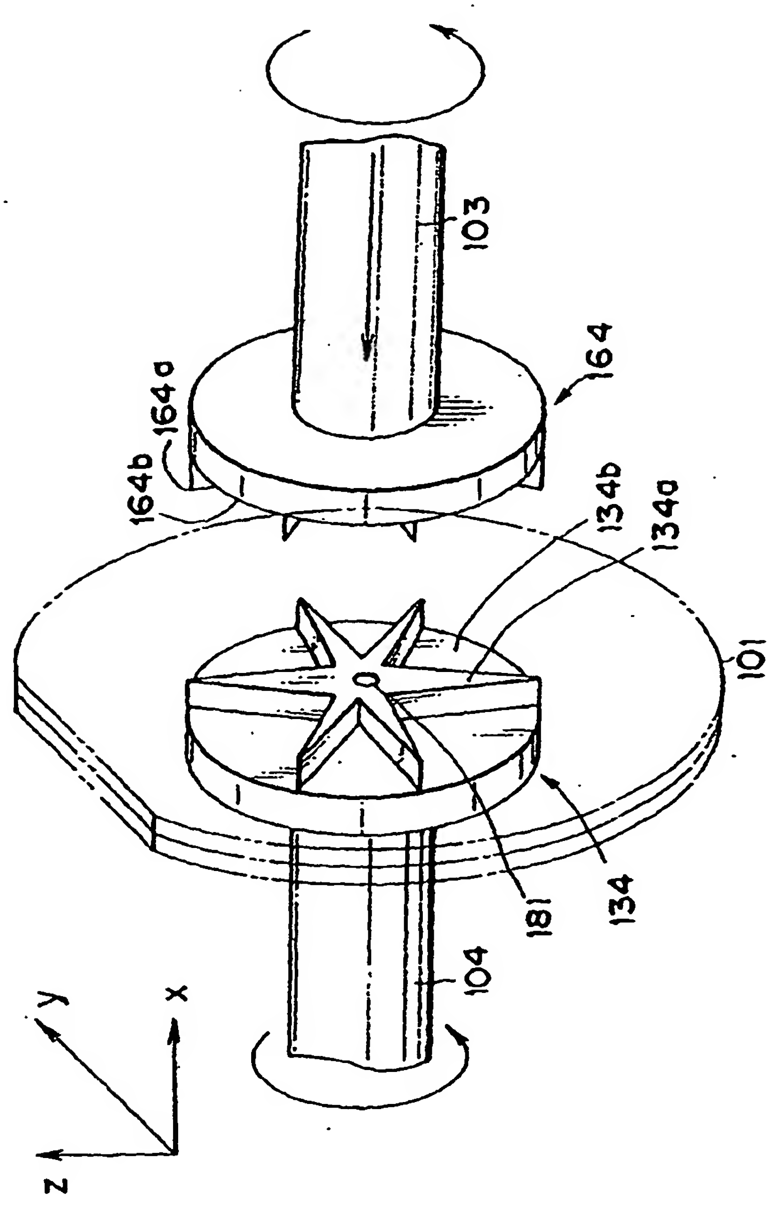


FIG. 21



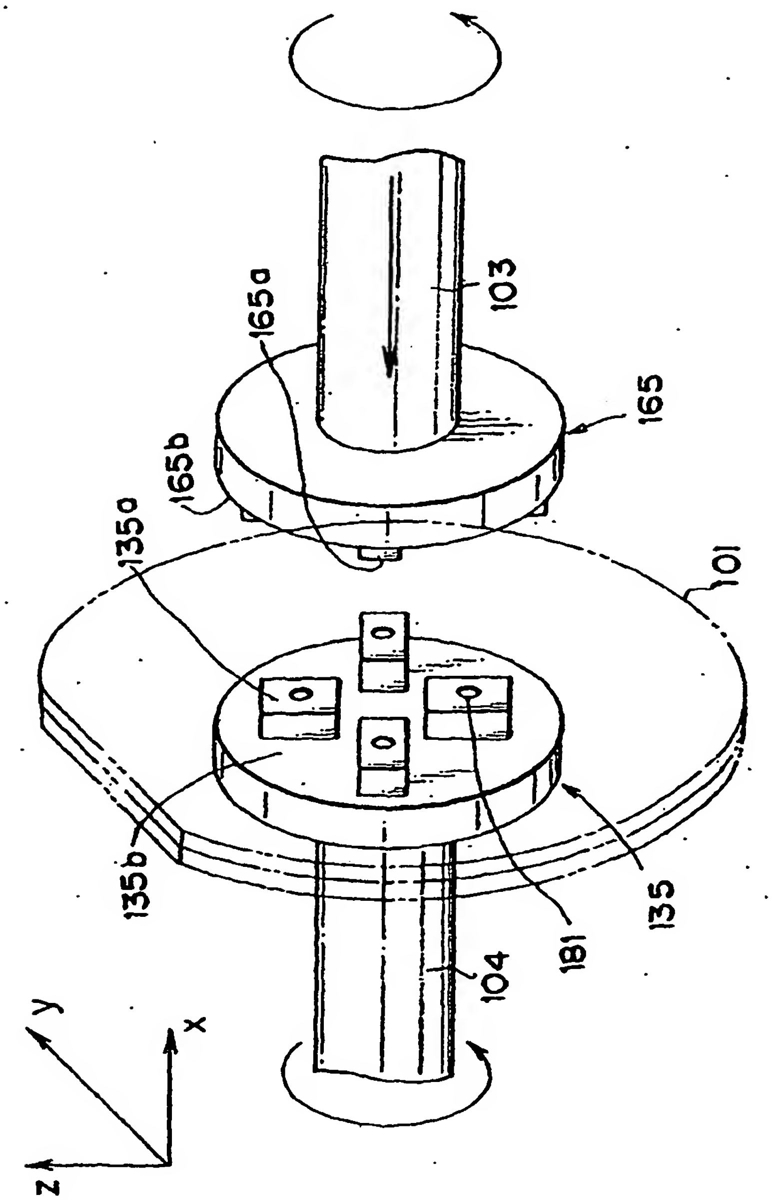
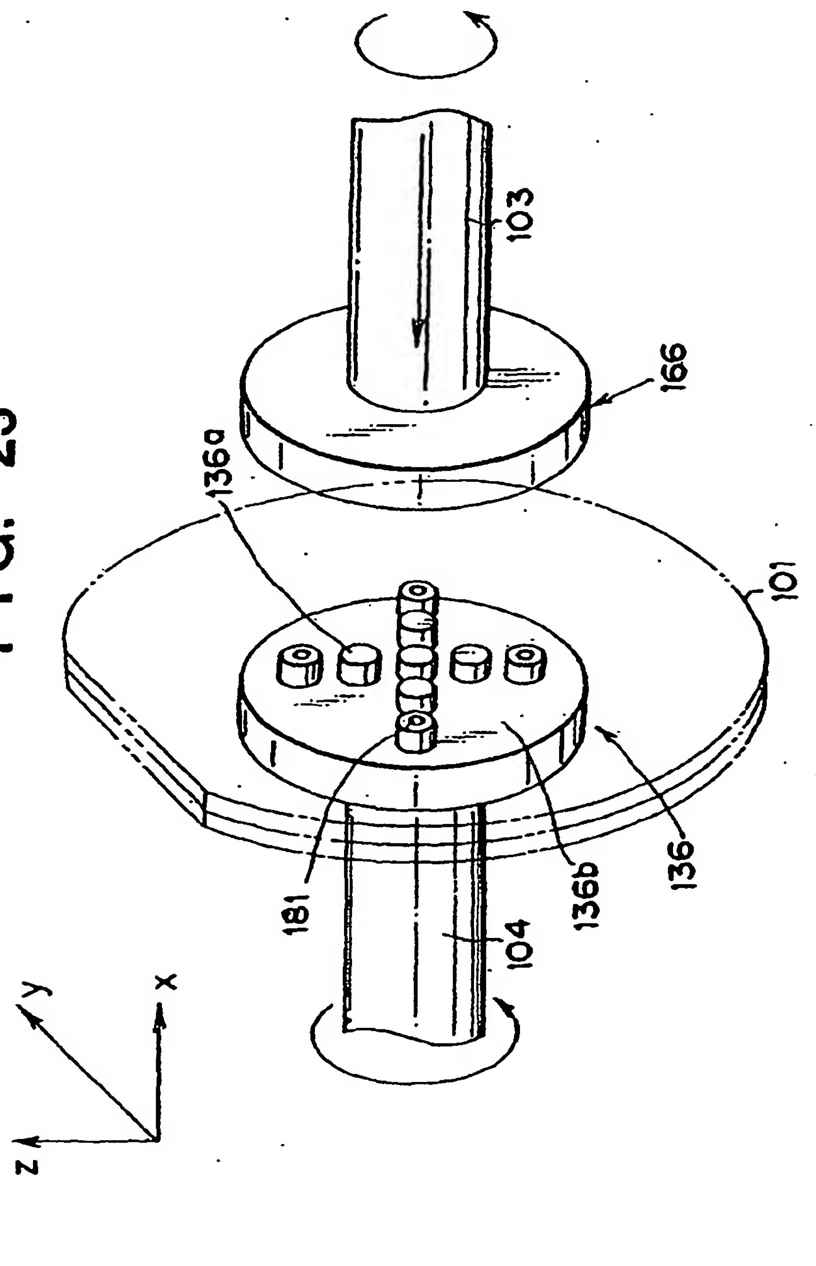


FIG. 22

FIG. 23



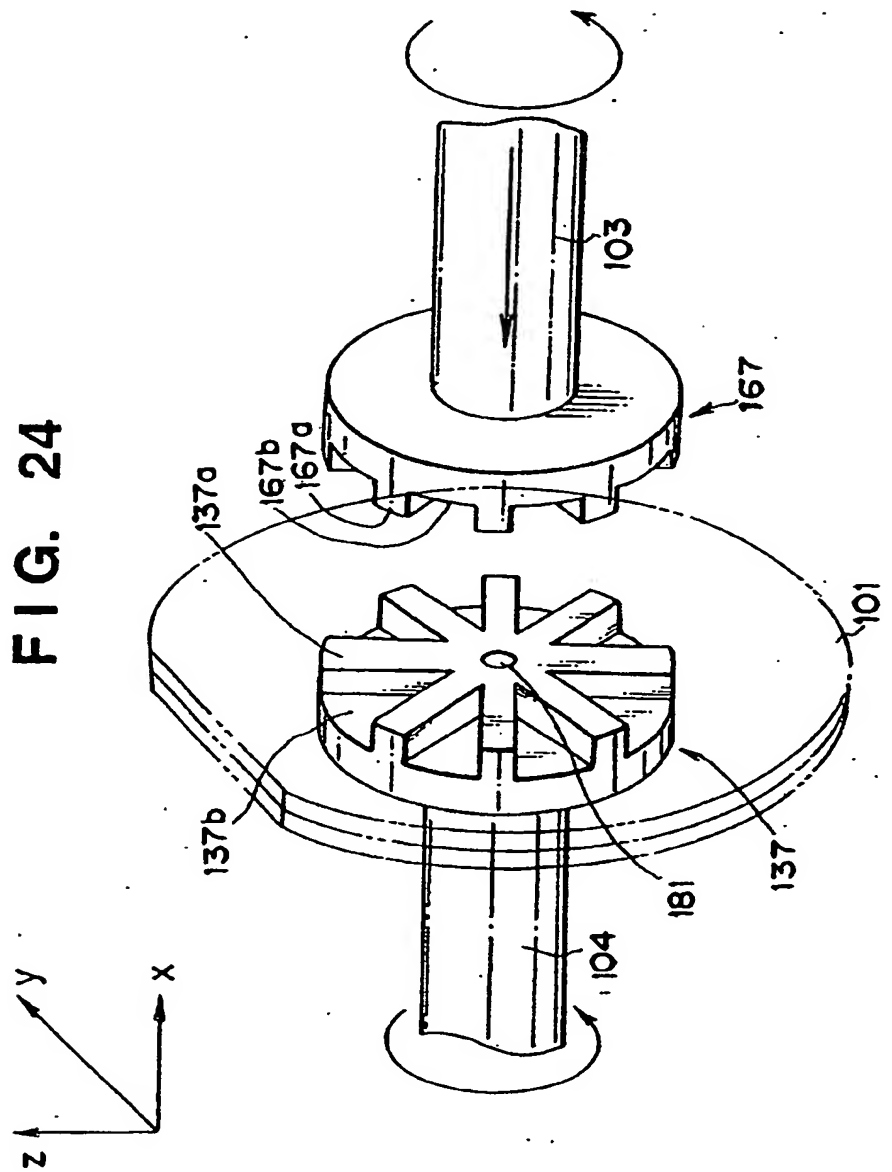


FIG. 24

FIG. 25A

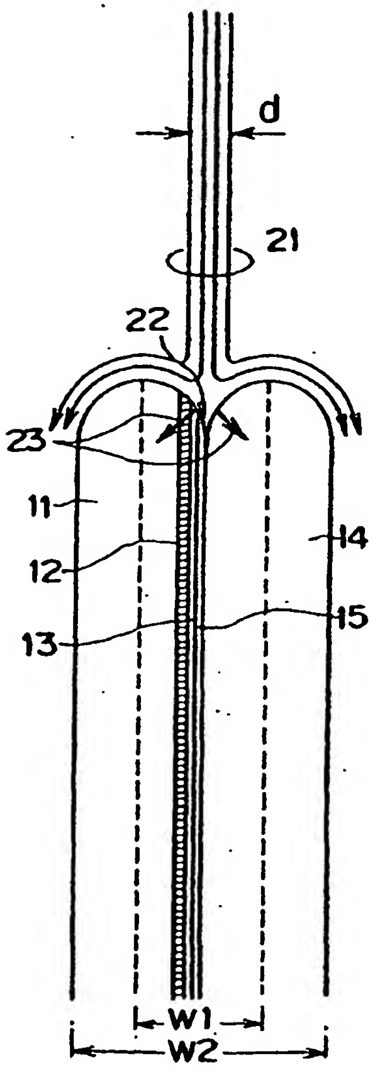


FIG. 25B

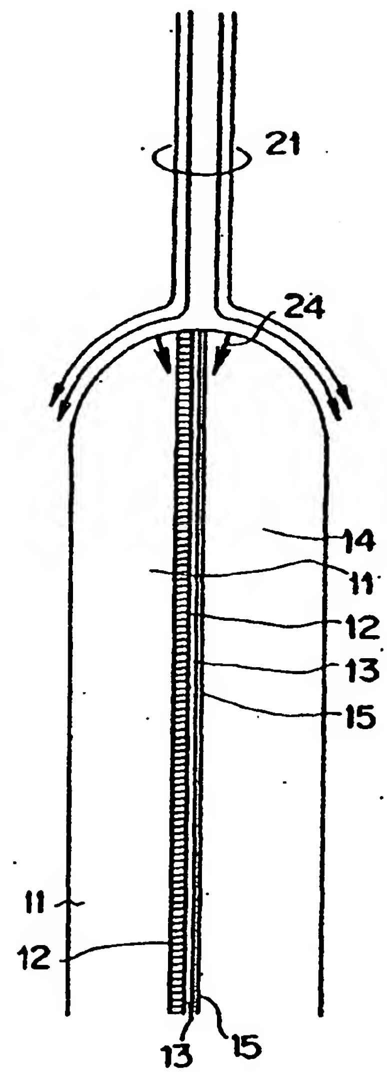


FIG. 26

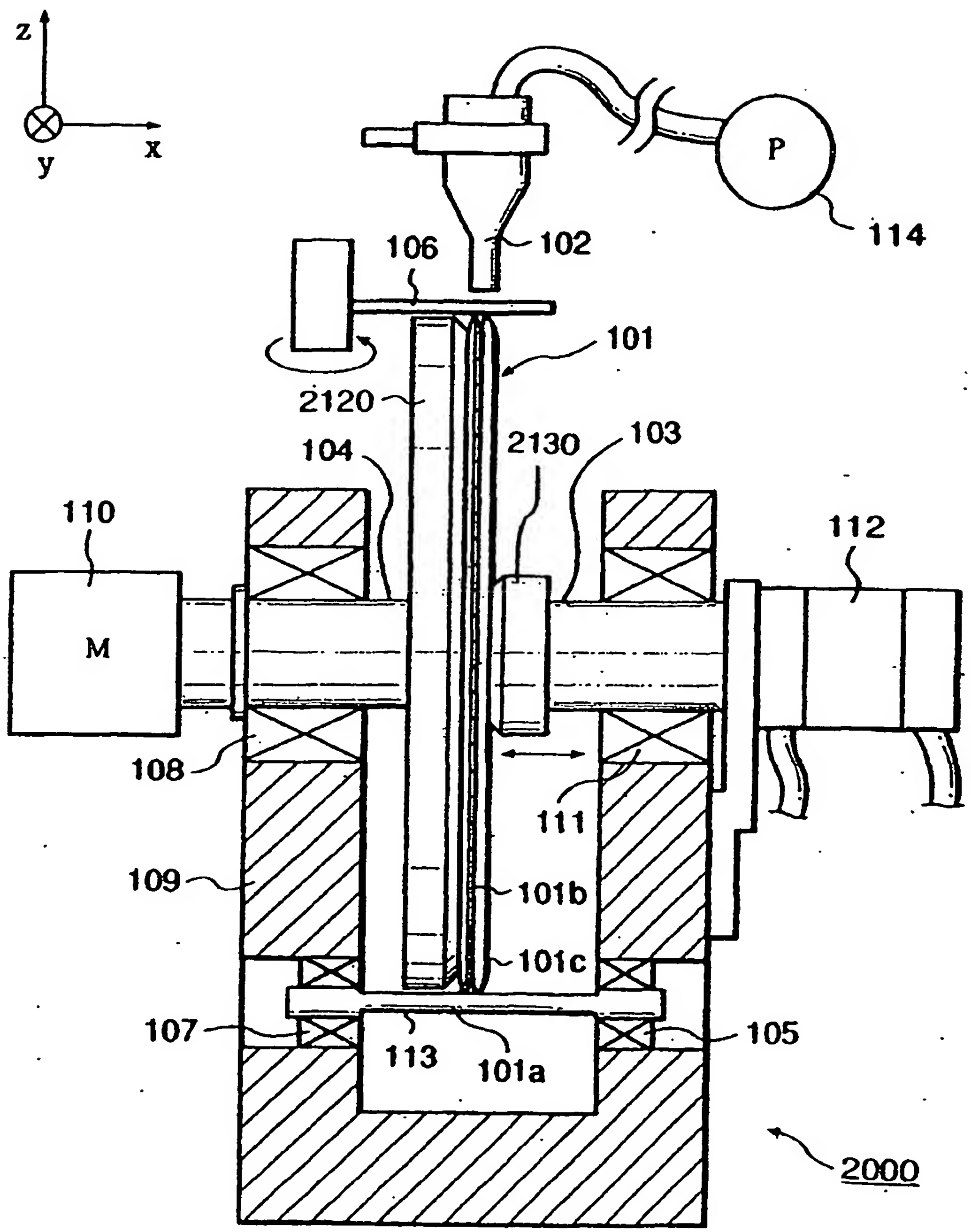

z
y
x
P
114
106
102
101
2120
104
2130
103
110
112
M
108
111
109
101b
101c
107
113
101a
105
2000

FIG. 27

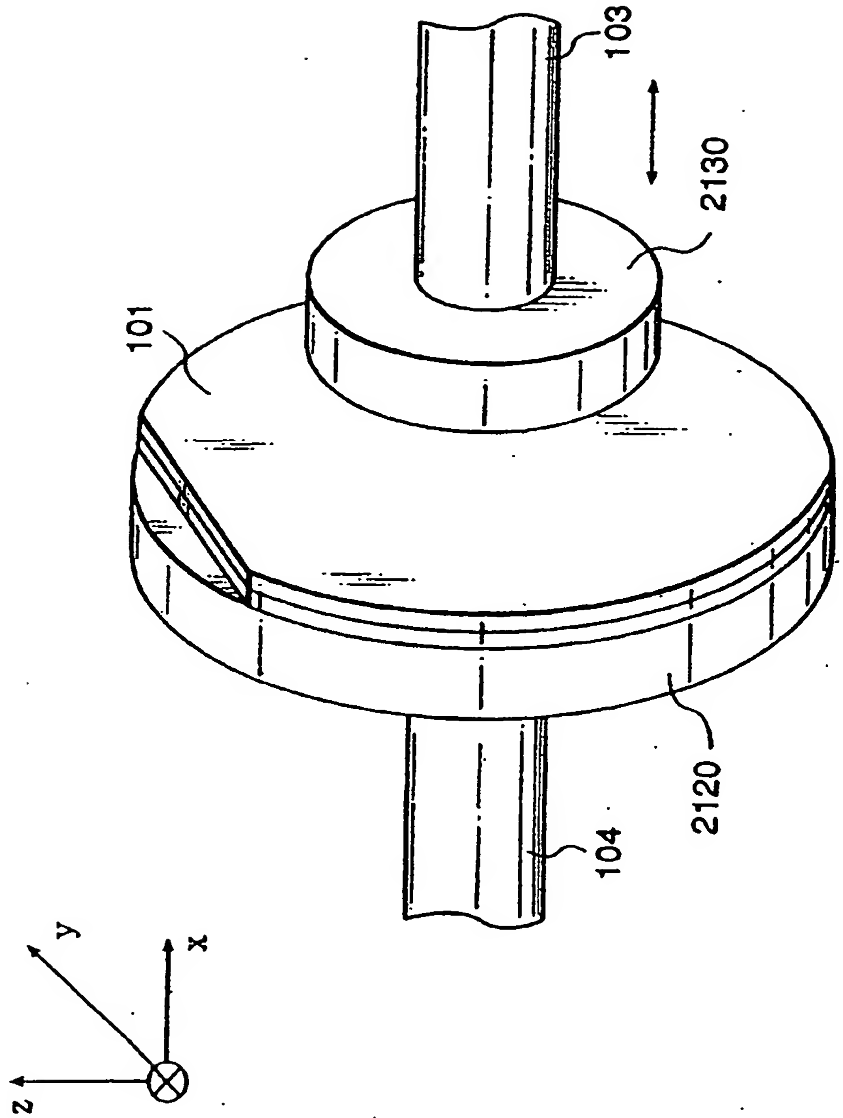


FIG. 28

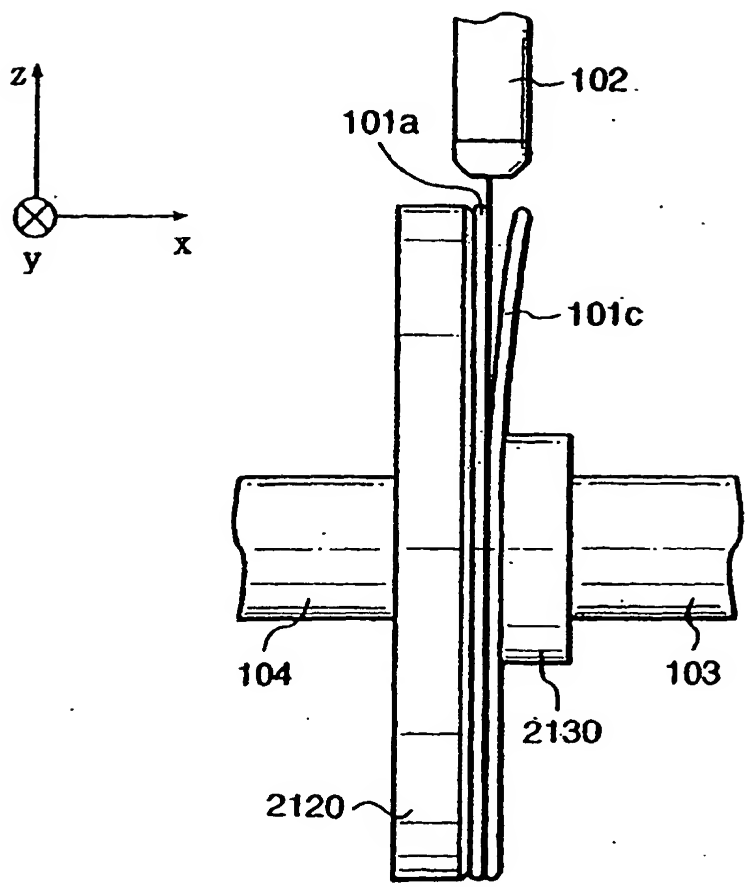


FIG. 29

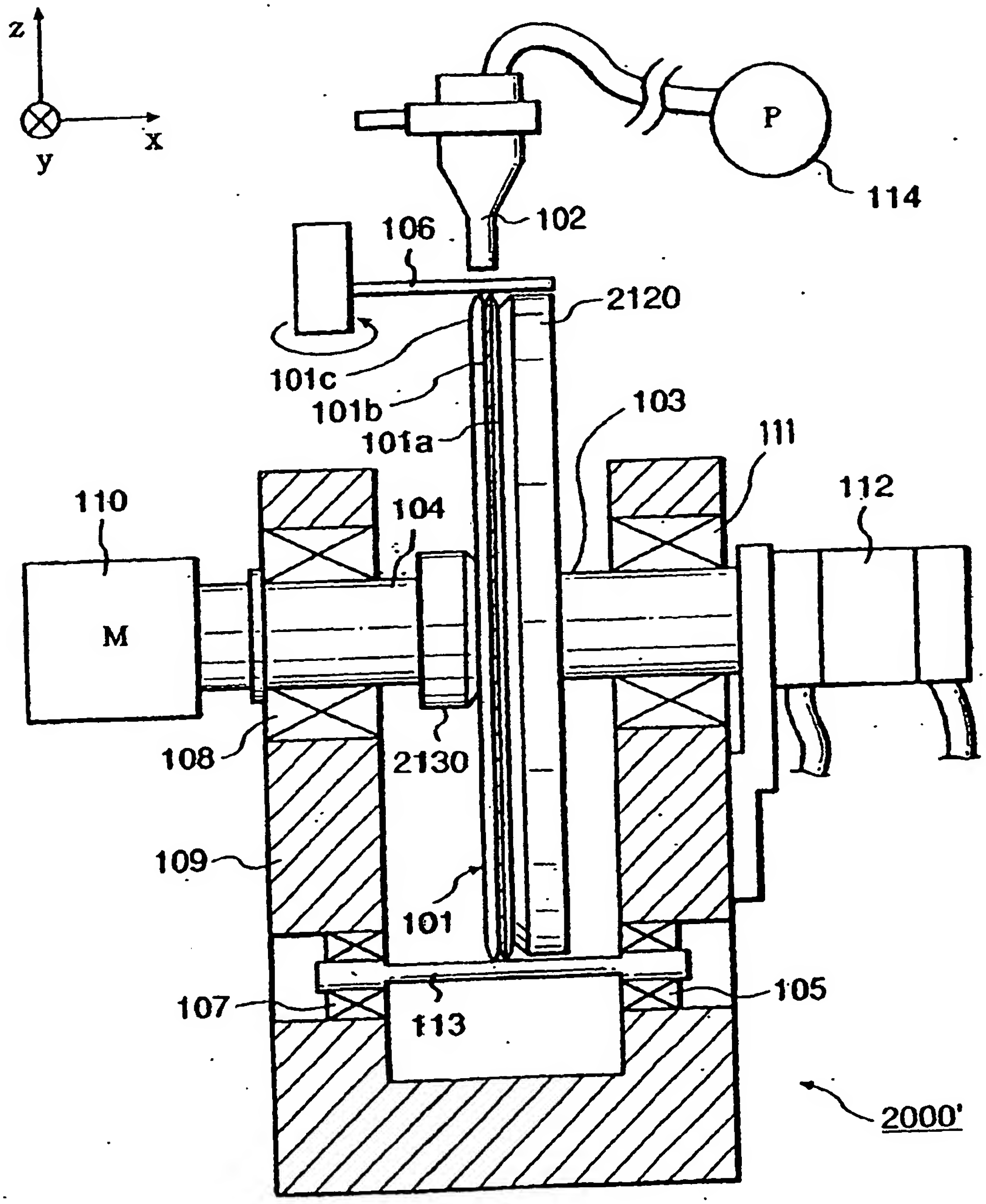

z
y
x
P
114
102
106
2120
101c
101b
103
101a
111
112
110
104
M
108
2130
109
101
107
113
105
2000'

FIG. 30

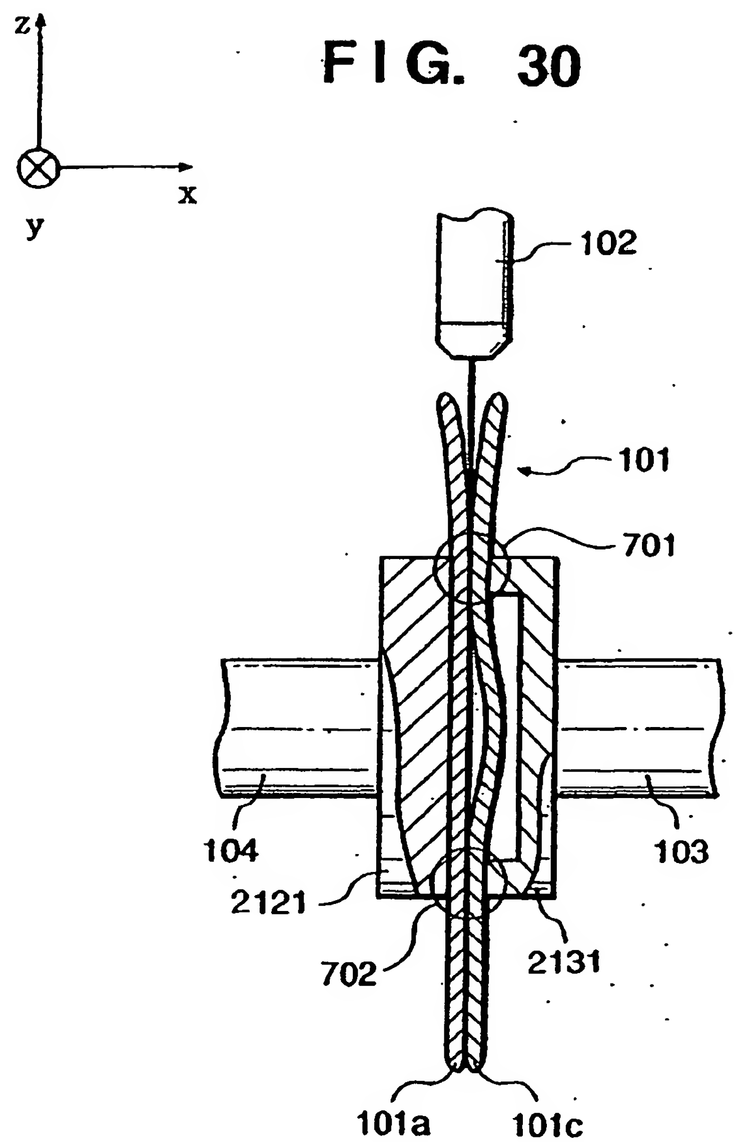


FIG. 31

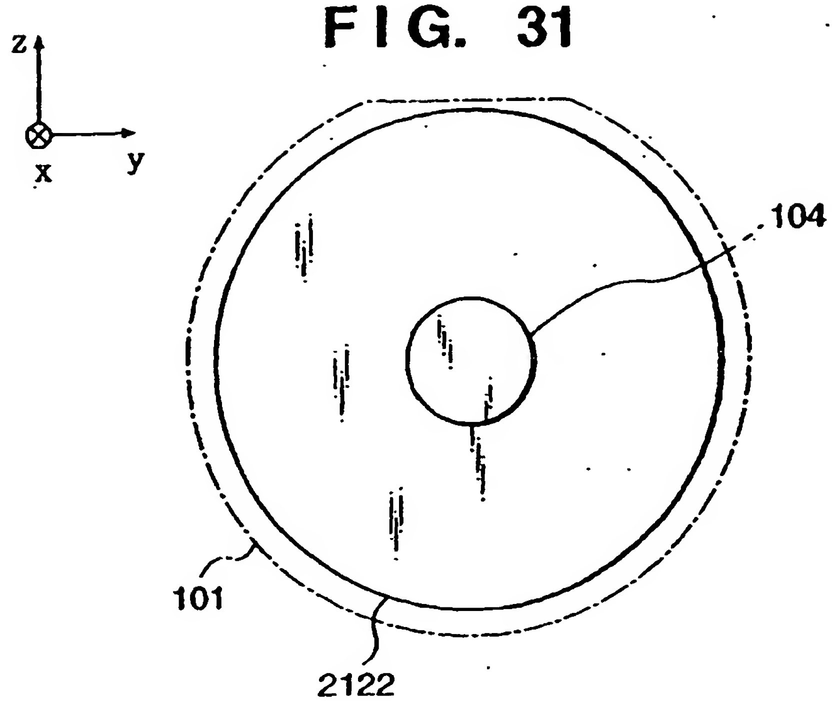


FIG. 32

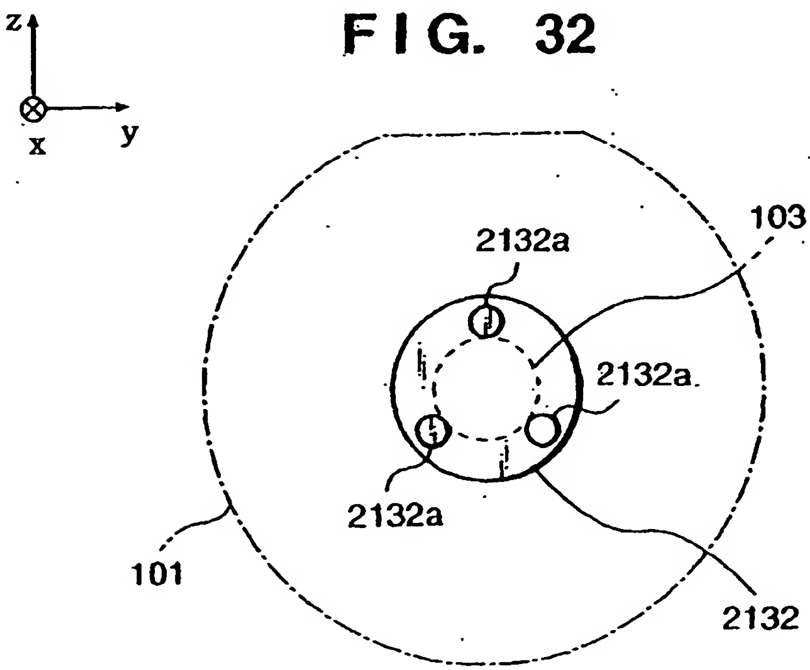


FIG. 33A

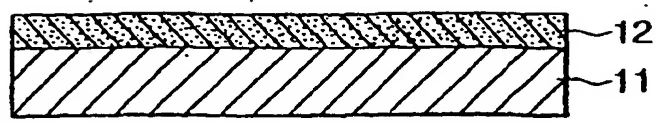


FIG. 33B

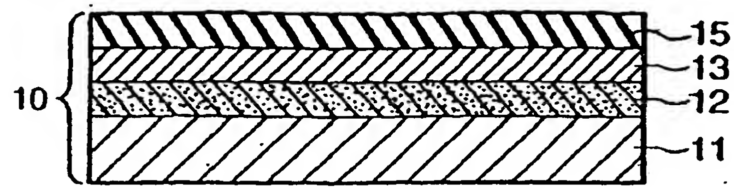


FIG. 33C

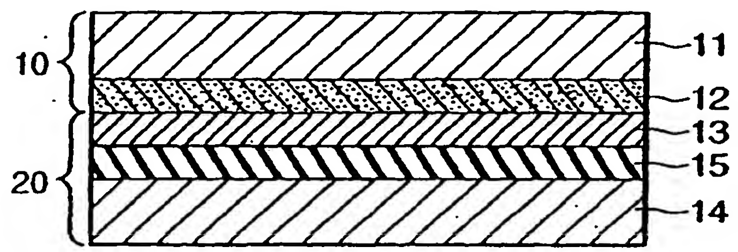


FIG. 33D

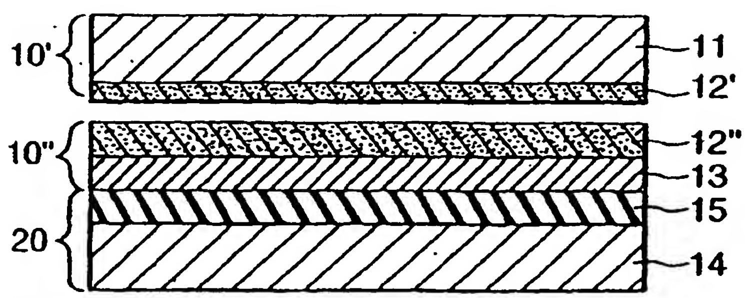


FIG. 33E